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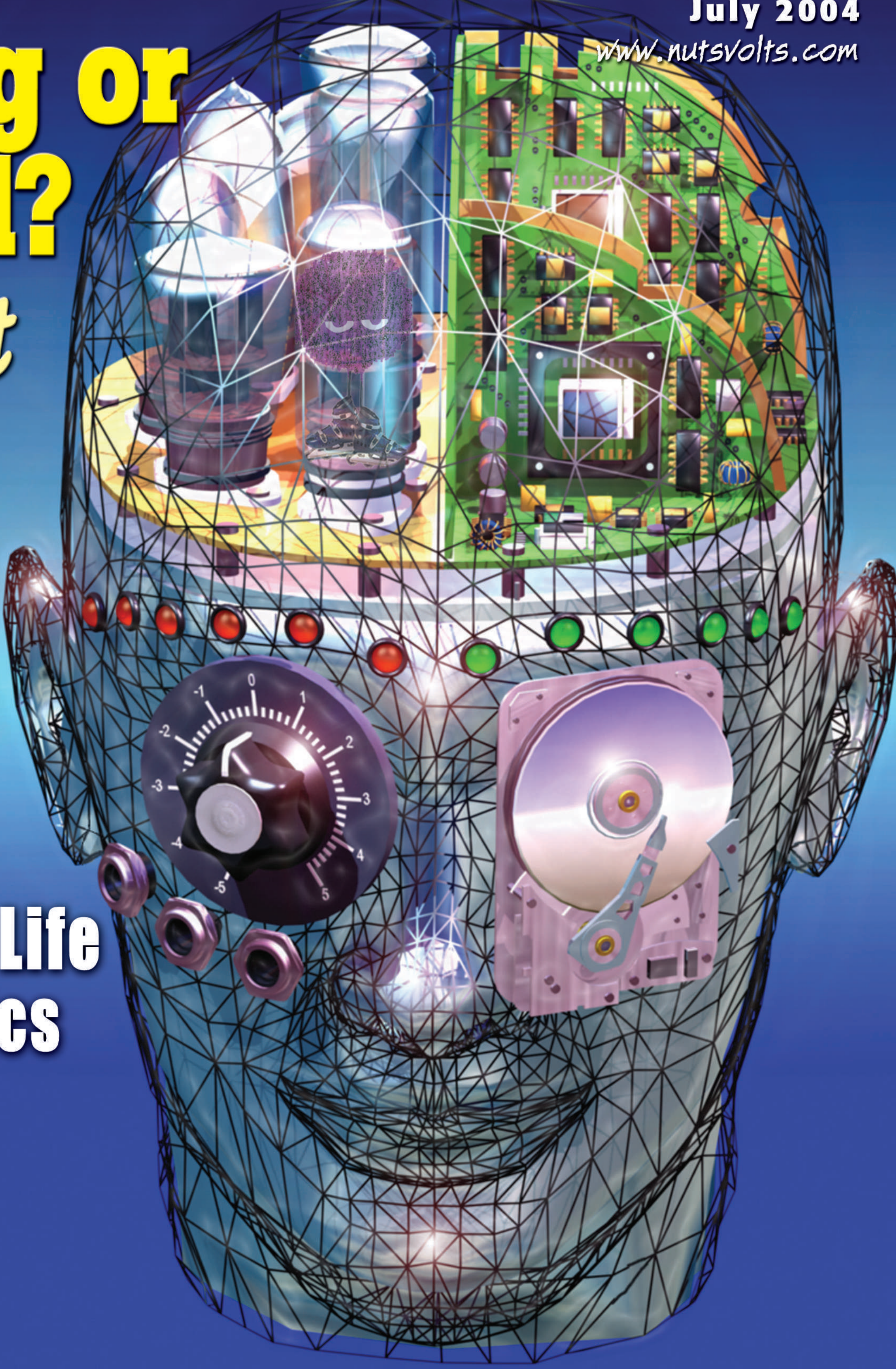

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Circle #71 on the Reader Service Card.

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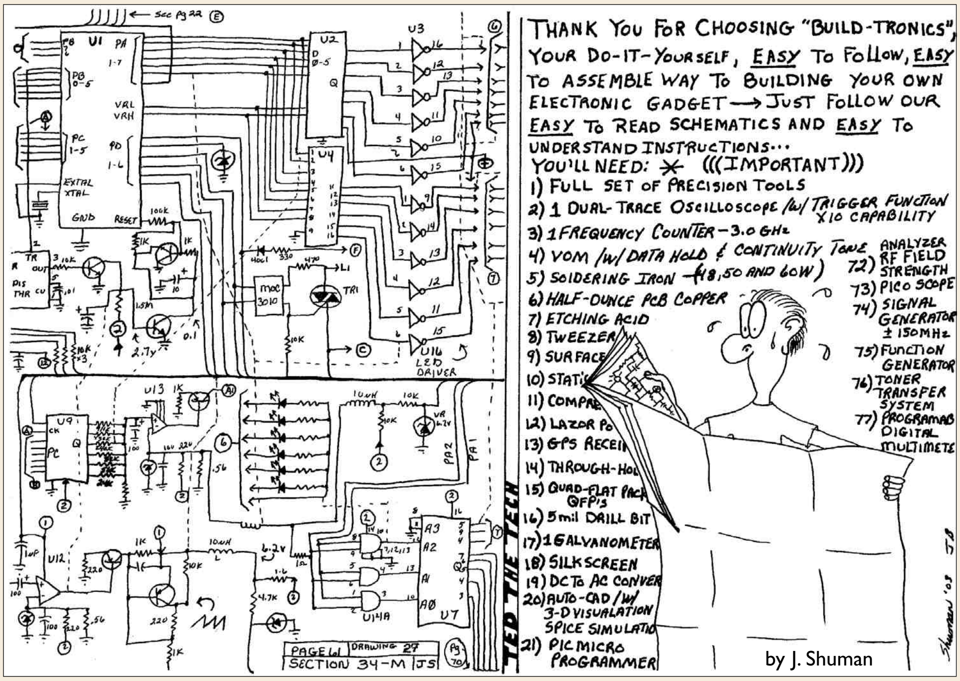

by J. Shuman

Dear Nuts & Volts:

Your feature article in the April 2004 edition of *Nuts & Volts*, "Magnetic Saturation and the 100 Amp DC Current Transformer" seems to be an attempt to reinvent the wheel.

Edward H. Hall discovered the Hall Effect in 1887. Hall Effect elements were coupled with semiconductors in the 1970s, all but eliminating the use of wire coils wound on square loop cores for metering and control (magnetic amplifier) purposes.

If you need to measure high DC currents, look in your Digi-Key catalog under "Transducer-Current" (page 1,227). You will find a listing of pre-trimmed Hall Effect Current Transducers with input ranges of 6 to 100 amps full scale at prices ranging from $19.00 to $30.00.

These transducers require only a source of +5 VDC or ±12 to 15 VDC excitation at a few milliamps with an operational amplifier or simple resister network for output scaling. Since primary-secondary coupling is through a Hall Effect element, the transducer is electrically isolated from the line. These units cover an input frequency range of 0-200 kHz. For units up to 1,000 amps, check the F. W. Bell Company.

For instruction of hobbyists on more modern technologies, an article in your publication on the Hall Effect would seem to be in order.

Farnham Cornia
via Internet

The existence of pre-made Hall Effect transducers does not eliminate the value of explaining the electromagnetic theory behind the operation of Mr. Glenn's circuit. — Editor Dan

Dear Nuts & Volts,

The June issue — page 95 — in "Tech Forum" has a schematic for a Gel-Cel Charger. The parts list appears to be missing a steering diode that is connected to the plus terminal of the battery. I suspect it is a low voltage GP silicone diode rated at 1 or 2 amps — something like a 1N4001.

Lynn Weber
Austin, TX

Dear Nuts & Volts:

You had me ... hook line and sinker with the April "Techknowledgey 2004" column. Then co-worker David M. LeBlanc noticed the little red box in the lower right hand corner of page 79. From there, it was easy. The fly eats near the golden arches — probably leftover Big Macs just casually dropped by a not-so-hungry Martian. Good April Fools picture (and article).

I really enjoy your magazine regularly.

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Micro Memories

The High Tech Rockman Becomes the Sound of '80s Guitar

Every industry has its own trade show. For consumer electronics, it's CES in Las Vegas, NV, for computers, it's Comdex, and for the music instrument industry, it's NAMM — short for North American Music Merchants.

In 1982, guitarist and inventor Tom Scholz — then best known for spearheading the multi-platinum group Boston — stole the show at that year's NAMM event in Atlanta, GA with a little black box that he called the Rockman. "It was just Tom, on his little pedestal with the Rockman and two headphones — one for him to listen to and the other for demonstrations," Bob Cedro, an engineer who would be hired by Scholz in the mid '80s, says. "One person heard it and he was amazed, told everybody, and, soon, the whole NAMM show was abuzz with 'you have to go see this device at the Scholz R & D booth.'

"People lined up down the hall, serpentined around, just to listen to this because it was only one at a time listening," Cedro adds. "They kept on picking it up to figure out where the wires were that connected it to the Marshall stack and Tom said, 'this is it!' He actually ran it on batteries and, at one point, clipped it to his belt just to prove that this was it."

The Adrenalinn packs in more effects.

Much Smaller — and Much Cheaper — Than an Amp

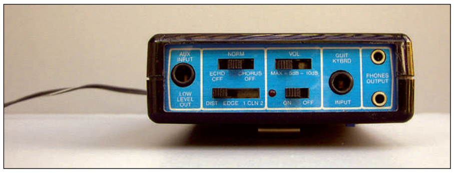
The Rockman did a pretty nifty job of recreating the smooth, creamy lead and crunchy distortion sounds that Scholz used on his Boston albums, but they were created with stacks of 100 watt Marshall amplifiers recorded at excruciatingly loud volumes and then fed through thousands of dollars of outboard sound processing gear to shape the tone.

In contrast, the Rockman was only slightly larger than Sony's cassette-based Walkman (hence the name) and retailed for a couple of hundred dollars — unlike a typical guitar amp, which could set a musician back a minimum of several hundred dollars — and often much, much more.

The Rockman's case was made of black plastic with a control panel and inputs at its top end and a battery pack for eight AA batteries in the other end. A belt clip allowed the unit to be worn by a guitarist on stage or while simply wandering around the house.

(Scholz eventually designed "The Rockadaptor," a much needed AC adaptor. It made the Rockman less mobile, but it also cut down on frequent trips to the 7-11 for new batteries.) Inside, the Rockman was crammed with circuitry designed by Scholz, an MIT graduate with Bachelor's and Master's degrees in Mechanical Engineering who got his start with Polaroid as its senior product designer. (Contrary to popular rumor, though, he did *not* invent the SX-70 instant camera. "I didn't even like the SX-70," he told *Rolling Stone* in 1978.)

The control panel — deceptively simple.



The Rockman was actually the *second* device that Scholz manufactured under his nascent Scholz R & D label. Its predecessor was the Scholz Power Soak — a box that allowed an amp to be overdriven at lower volumes and was used extensively on the Boston albums.

It was with the Rockman, however, where Sholz struck it big in the marketplace. The unit had the standard quarter-inch input and output jacks for electric guitars, but also two one-eighth inch mini-jacks for headphone listening and shipped with a nifty set of Walkman-style headphones (that, unfortunately, were as flimsy and prone to breakage as Walkman-style headphones.)

It had four basic sounds: Clean 1, Clean 2, Edge, and Distortion, along with a jangly-sounding chorus effect and a slap echo. Both effects were controlled with a three-way sliding switch, meaning both could be turned on or that one or the other effect—but not both—could be switched off. While its piercing but warm lead sound was pretty amazing, its clean sounds were also very effective, as well, especially when the chorus was switched on, producing a sparkling tone that sounded particularly good when a single coil guitar — like a Fender Stratocaster — was plugged into it.

The Sound of the '80s

Scholz originally designed the Rockman as a practice device and for the home recordist. In the mid-80s, I, like thousands of other guitarists, recorded demos using a Rockman plugged into a cassette four-track machine — another then-new piece of technology. Being able to record my own songs with screaming guitar solos without waking the neighbors at two in the morning was a very, very good thing.

A funny thing happened to the Rockman — a number of professional musicians began discovering the same thing. Because the Rockman was so handy and easy to use, its sound became one of the icons of the 1980s, along with Yamaha's DX7 synthesizer and Roger Linn's drum machine, which was also originally designed as a practice device, but quickly ended up replacing live drummers on many a pop hit.

Bob Cedro says, "All of a sudden, bands from Alabama to ZZ Top started using the Rockman and even a friend of mine — guitarist Elliot Easton from The Cars — was prolific using a Rockman for music for ads. The next thing you knew, you heard all these ads pop up on TV that had the Rockman. You could tell immediately — it's the perfect compressed, processed guitar sound, which always sounded great and the same, whether it was a Stratocaster or a Les Paul you plugged into it." Eventually, Scholz himself used it on Boston's later albums.

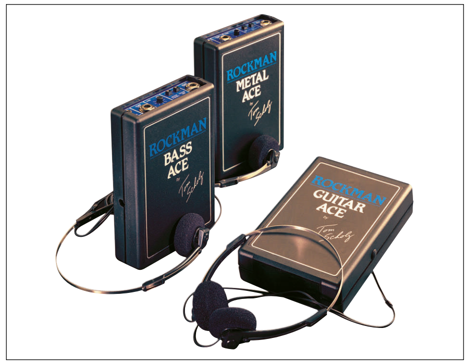
Even keyboardists began to use the Rockman for its distortion effects. Jan Hammer ran a Minimoog synthesizer through one for his *Miami Vice* soundtrack work to simulate the sound of distorted electric guitar.

Still on the Market

In 1995, Scholz, wanting to focus more on his music and less on business decisions, sold his Rockman line to Dunlop Manufacturing in Benicia, CA. Bob Cedro, who got his start in the musical equipment business 10 years earlier when he was hired by Scholz's company, joined Dunlop. There, he redesigned Scholz's product slightly — mainly updating its switches, which were prone to failure, with, "one tactile switch which has the characteristics of 500,000 operations before it goes south." He also redesigned the battery to take two nine-volt batteries, rather than the cumbersome eight AAs.

Today, the Rockman — based on Scholz's original design, but upgraded by Cedro — is available in four flavors: a basic model called the Guitar Ace (most similar to the original), a Metal Ace with additional distortion, a Bass Ace, and a version designed to make an electric guitar resemble its acoustic counterpart.

Each unit sells for about $100.00 — half of the Rockman's original price. However, the unit has since been succeeded as a state-of-the-art product by newer designs, such as Line6's Pod and GuitarPort products and Roger Linn's AdrenaLinn box, each of which is capable of many more sounds and effects than the "simple" Rockman. Many home recording programs, such as Cakewalk's Guitar Tracks Pro, have built-in amp modeling plug-ins, as well.



There's a Rockman for every musician.

Given that so many musicians came of age in the 1980s practicing and recording with the Rockman — and that it was so enormously popular on hit records — it has earned its place in the music field as a product that paved the way from huge stacks to small, handheld devices.

Today, recording engineers and many musicians have no qualms about using devices like the Pod and AdrenaLinn to record with — they are quick and easy to set up, easier to control, and their sounds are more repeatable than those of many tube-based amps, but these products probably wouldn't have existed if the Rockman hadn't paved the way. **NV**

Basics For Beginners

Just For Starters

Starting a New Design — Part 2: State Machines and Microcontrollers

Getting started on a new design isn't easy when you have trouble figuring out what types of circuits are necessary to implement the project's requirements. Last month's article discussed how to decompose high level requirements into a set of architectural building blocks and then presented analog and digital implementations of a basic LED blinking circuit.

In this final installment of the two part series, we'll see how digital logic can be modified to produce arbitrary blinking patterns. Blinking LEDs may not be a project dear to your heart, but the techniques used to design such a circuit can be applied to general projects. This article continues by explaining how a microcontroller implements diverse algorithms with software and thereby serves as a flexible, reconfigurable design element.

Blinking With Counters

Figure 1 shows the basic 2 Hz LED blinking circuit presented in last month's article. The two most significant bits — bits 13 and 12 — of the counter increment every 125 ms. Twelve counter bits — 11 through 0 — divide the 32.768 KHz clock by 2^{12} or 4,096, which yields a period of 125 ms. The OR gate turns the LED on when both bits are zero and turns it off during the remaining count states (01, 10, and 11), forming a 25% duty cycle.

Counters provide excellent flexibility in logic design because each count value — or state — provides an opportunity to perform a unique task. The 14-bit counter provides 2^{14} — or 16,384 — unique states. Most of these states are useless for our LED blinking example because the human eye has a limited frequency response. With the counter incrementing at 32.768 KHz, each state lasts for about 30 microseconds. The example in Figure 1 operates by effectively combining many unique counter states into two observable events. Bits 13 and 12 remain static for 4,096 count values. Therefore, the LED on state is actually 4,096 count states and the off state is 12,288 count states.

State Decoding

We can create more complex blinking patterns from the counter circuit by augmenting the state decoder logic, which is just an OR gate right now. The first step is to use a third counter bit — bit 11 — to form a three-bit LED state vector that increments at half the previous period, 62.5 ms. The eight resulting states are listed in Table 1, along with an arbitrary blinking pattern: two short blips and a blink.

Once we have developed the truth table to relate the counter state to the LED state, completing the design is just a matter of coming up with logic to implement the truth table. Figure 2 shows the logic gates that create our more complex blinking pattern. Keep in mind that the LED is turned on when the logic output is zero.

You can see from this brief demonstration that more complex and longer blinking patterns can be created by adding state bits and decode logic. Use a 16-bit counter if you want a two second repeating sequence. These are the beginnings of finite state machines, which include next-state logic in addition to

Figure 1. A 2 Hz blinking LED with counter.

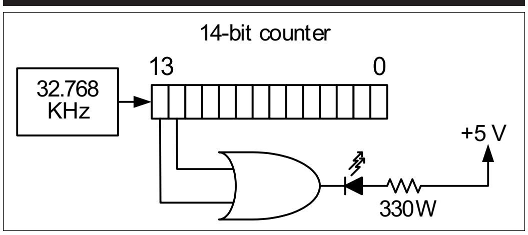


Figure 2. Three-bit blinker logic.

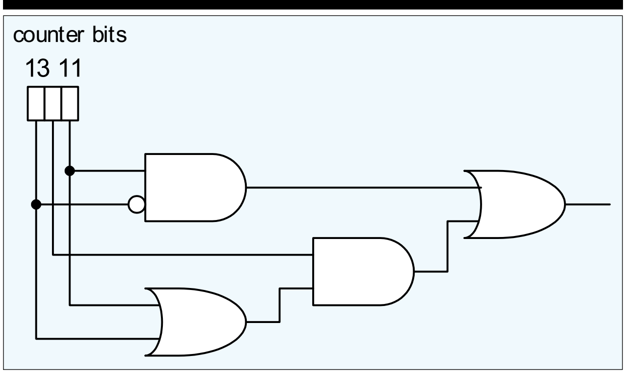
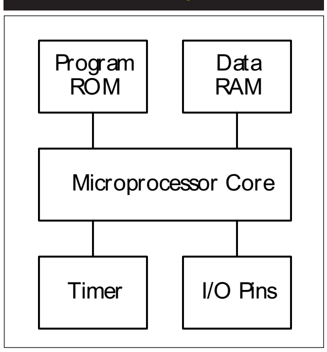


Figure 3. Microcontroller block diagram.



decode logic. A state machine may not always increment between consecutive states. Instead, it can jump around in its state space (i.e., counter value) similar to the way a computer program branches back and forth between routines. State machines can be as simple as our LED blinker or complex enough to rival a small microprocessor.

State Machines in Software

Hardware state machines are appropriate in many circumstances. Simple tasks — such as blinking an LED — are readily solved with a few logic gates. Complex tasks that must be performed with utmost speed are natural applications for hardware state machines. Yet, there is a large middle ground of algorithms that have relaxed speed requirements. Software running on a microprocessor can implement these state machines. Software implementations allow state machines and algorithms to be readily changed without having to connect new logic gates as with hardware.

General purpose microprocessors are often too bulky for small projects. Your microwave oven doesn't have a Pentium in it and likely makes do with a microcontroller that costs around $1.00. Microcontrollers contain small microprocessors along with some memory and a few basic peripherals. They are often self-contained devices that require only power and a clock to function. As such, microcontrollers are perfect devices for implementing control algorithms that do not require high speed processing.

Microcontroller Timing

Practically every microcontroller contains at least one timer peripheral that can be programmed to generate an interrupt at regular time intervals. The timer is a counter that is similar to the discrete counter discussed previously. The discrete counter provides eight blinking states with a 62.5 ms increment period. Therefore, the microcontroller's timer would be programmed to generate an interrupt every 62.5 ms.

Programming a timer varies among specific microcontrollers. Generally speaking, a timer is clocked using a derivative of the microcontroller's main clock. If the microcontroller runs at 8 MHz, the timer may be clocked at 1 MHz. In this case, the timer would be programmed to roll-over and generate an interrupt every 62,500 cycles.

Microcontrollers also contain input/output (I/O) pins that software can read and write. These pins are used to query status from the outside world and to control actions such as blinking an LED. Figure 3 shows a general purpose microcontroller that would be used in our application. Note the on-chip, read only memory (ROM) for software storage and the random access memory (RAM) for general software variables.

Blinking With Software

You can design software to blink an LED after creating a regular interrupt with the microcontroller's timer. The microcontroller invokes software called an interrupt service routine (ISR) whenever the timer generates an interrupt. Between interrupts, the microcontroller executes a main routine. The main routine initializes the system and then remains in an idle loop for the rest of the time. All of the blinking functionality is time-driven and implemented in the ISR.

State Value	LED On?
000	Yes
001	No
010	Yes
011	No
100	Yes
101	Yes
110	No
111	No

Table 1. Three-bit blinker truth table.

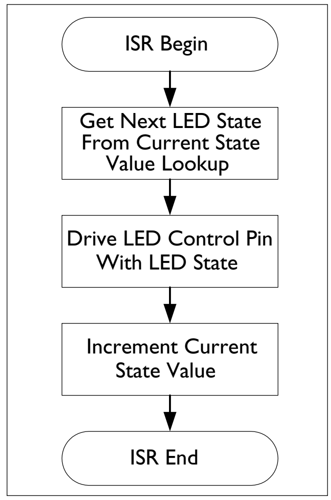


Figure 4. LED blinking interrupt service routine.

Figure 3 shows a flow chart for the LED blinking ISR. The ISR maintains a current state value that is incremented on each interrupt. When the ISR is first invoked, it references a predefined table that contains the blinking pattern in Table 1. Each current state value has an associated LED on/off state. The LED state is driven to a microcontroller output pin that drives the LED.

Since there are only eight defined states (though you could implement as many as you wish), the ISR must be sure to wrap the state value back to zero when the current state is seven. Otherwise, the state value would increment past the end of the blinking lookup table and undefined operation would occur. The details of actually programming a microcontroller to perform these tasks vary with each type of device. There are variations on how timers and I/O pins are configured and on how software and ISRs are loaded into memory.

Architectural Considerations

There is more to learn about how to use discrete logic and microcontrollers to solve design problems. *Complete Digital Design* covers more advanced logic design techniques and microcontroller architecture and implementation. It is important to understand how architectural elements add both flexibility and complexity to a design. Working with microcontrollers raises the level of complexity somewhat, but provides great flexibility through reprogramming. Going the hard wired logic path may be simpler for certain projects and also gives a potential performance improvement when necessary.

When you determine a pattern or algorithm that must be executed, a state machine may be the architectural solution. How you choose to implement that state machine will depend on the resources you have available and how each technology compares on capability and complexity. **NV**

About the Author

Mark Balch is the author of *Complete Digital Design* (see **www.completedigitaldesign.com**) and works in the Silicon Valley high tech industry. His responsibilities have included PCB, FPGA, and ASIC design. Mark has designed products in the fields of telecommunications, HDTV, consumer electronics, and industrial computers. In addition to his work in product design, he has participated in industry standards committees and has presented work at technical conferences. Mark holds a bachelor's degree in electrical engineering from The Cooper Union in New York City. He can be reached via Email at mark@completedigitaldesign.com

Electronic Theories and Applications From A to Z

Let's Get Technical

Error Detection and Correction: A Survey of Selected Hardware and Software Techniques

In the case of a communication system, errors happen while information is being transmitted, while it is being delivered to its destination, or while it is being received. Perhaps a stray magnetic field sliced through a floppy disk and altered a few 0s and 1s. Maybe a lightning strike produced a spike in the power lines, which, in turn, caused a few cells in a RAM on a computer's motherboard to change.

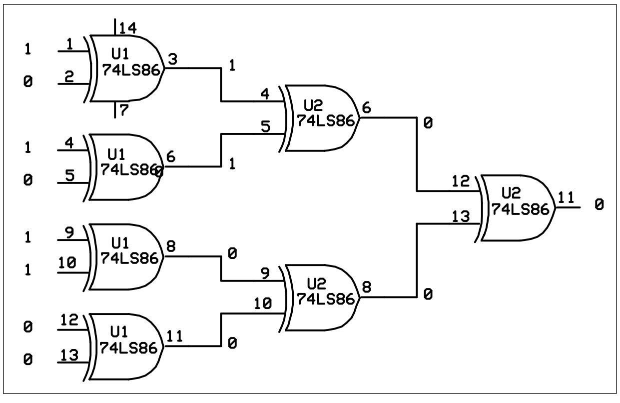
However the errors occur, is there anything we can do to protect our information? The answer is yes. In fact, there are many things we can do, with each hardware or software technique falling into one of two categories: error detection or error correction. Error detection is easier to do than error correction, as we will see.

The first hardware technique involves the use of a parity bit. This bit is stored with a group of data bits and is used to indicate the even or odd parity of the data. Even parity means the number of 1s in the data (including the parity bit) is even. Odd parity means the opposite. Table 1 shows a few sample data items and their associated even and odd parity bits.

The even and odd parity bits are always complements of each other. Figure 1 shows how a single parity bit can be generated using exclusive-OR (XOR) gates. The XOR gate outputs a 0 when its inputs are the same (both low or both high) and a 1 when its inputs are different. The input data 10101100 is broken into four groups of two bits, with each pair driving an XOR gate. The eight input bits are reduced to four intermediate bits, then two intermediate bits, then to a single output bit that represents the even parity for the data. Using an exclusive-OR gate as the last gate will generate an odd parity bit.

So, with only a handful of gates, we are able to generate odd or even parity bits. Now, after the parity bit is generated, it is stored with the data or transmitted with it to a receiver. When the data is read back or received, its parity is checked. If the parity does not match, you have detected an error.

Figure 1. Generating an even parity bit.



Unfortunately, a single parity bit has limitations. It can only detect odd-numbered bit errors. If one bit — or three, five, or seven bits — change, the parity will also change and the error will be detected, but, if an even number of bits change, the parity will remain the same and the error will go undetected.

The limitations of a single parity bit can be overcome by using multiple parity bits. In fact, by using just four parity bits, we are able to detect and correct single bit errors in our eight bits of data. Figure 2(A) shows how four parity bits (three odd and one even) are generated using different groups of bits from the input data. These four bits are called check bits and are transmitted or stored with the original eight data bits.

In Figure 2(B), the 12 received bits are again used to generate four parity bits, with these bits representing the error code. An error code of 0000 indicates that no errors have occurred. Any other error code will indicate the specific bit or even groups of bits in error. This technique was developed by Richard Hamming in the 1950s. Table 2 shows the four-bit error codes for the Hamming code used in Figure 2.

A deliberate error was introduced into data bit 4. The resulting error code of 1010 correctly identified this single bit error. Once a single bit error has been identified, it is easy to fix it: simply invert the bit that is incorrect.

The ability to detect and correct a single-bit error is important and useful. The price that we pay for this ability is the cost of the four check bits attached to each eight-bit data item. Thus, we have a 50% memory overhead (or bandwidth overhead, during transmission) that must be an acceptable trade-off in order to get the benefit of single bit error correction.

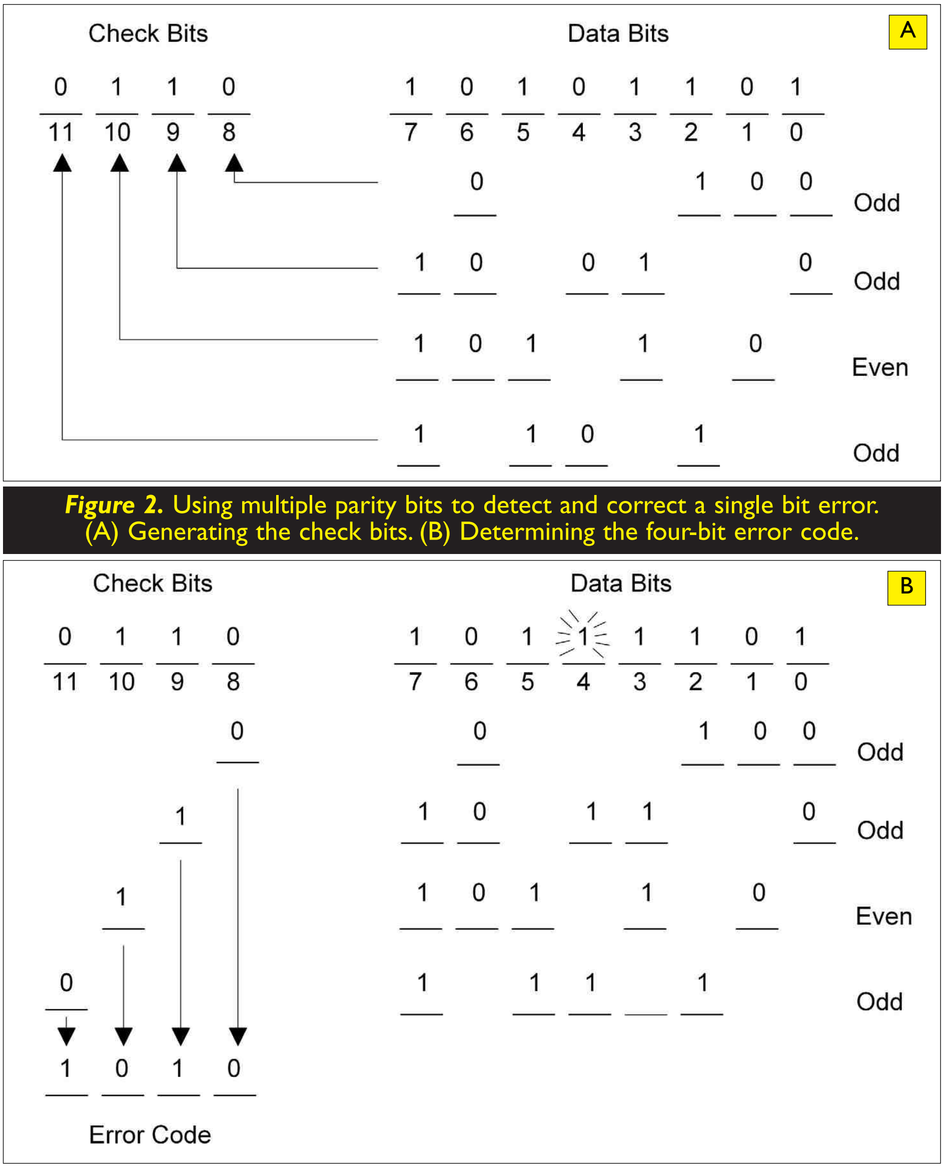


Figure 2. Using multiple parity bits to detect and correct a single bit error. (A) Generating the check bits. (B) Determining the four-bit error code.

A third hardware technique that can be used with a serial stream of data uses multiple bits to create a check sequence. This technique is called a Cyclic Redundancy Check (CRC) and can be used with bit streams of varying lengths.

The basic method is to treat the serial data stream as a large, binary number. By dividing this number by a predefined binary polynomial, we end up with a remainder pattern (the check sequence) that gets tacked onto the end of the original data.

The check sequence essentially turns the serial stream into a number that is evenly divisible by the polynomial. So, on the receiving end, when the received data (which includes the check sequence) is passed through the CRC circuit, the resulting check sequence will be all 0s if there are no errors. Any 1s that show up indicate one or more errors in the bit stream, but we will not know where they are.

Suppose the data to transmit is 10101100 and the four-bit polynomial is 1011. Generating the check sequence is accomplished through the use of Modulo-2 arithmetic (once again using exclusive-OR). This process is illustrated in Figure 3. A three-bit pattern of 000 is tacked onto the end of the original data. This is done to reserve room for the actual three bits of the check sequence once they are determined.

At each step, four bits of data are XORed with the four-bit polynomial 1011. This process repeats until there are no more bits left in the data. The final three bits remaining are the CRC check sequence (011). This sequence is now tacked onto the end of the original data (giving us 10101100011) and transmitted.

On the receiving end, the same process is used again, with the 011 sequence replacing the original three 0s. If there are no errors, the remainder will be 0. Change one of the bits yourself and verify that the remainder is non-zero.

The CRC generator is easily constructed using a few XOR gates and a shift register. Figure 4 shows the schematic of the CRC generator for the 1011 polynomial.

A four-bit divider polynomial requires a three-bit shift register to hold the three remainder bits that make up the check sequence. After all bits have been clocked into the circuit, the shift register will contain the three remainder bits (LSB on the right and MSB on the left).

An eight-bit polynomial would require a seven-bit shift register (and seven 0s tacked onto the original data to begin the process). In general, the shift register has one less stage than the number of bits in the polynomial. Table 3 shows some typical CRC polynomials and their uses.

Software techniques for performing error detection and correction are especially useful in the world of networking and the Internet. When we download a web page or send an

Figure 3. Generating a CRC check sequence.

```
1011 | 10101100000
       1011
       0001110
          1011
          01010
           1011
           0001000
               1011
               0011
```

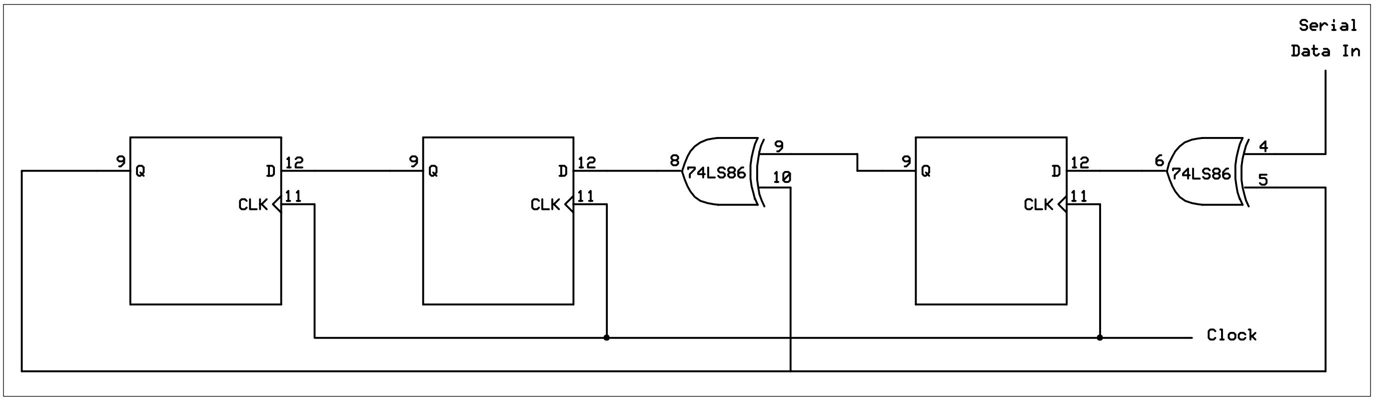


Figure 4. The three-bit shift register used to create a CRC check sequence.

0		8	16	24 31
Source Port			**Destination Port**	
Sequence Number				
Acknowledgment Number				
Offset	**Reserved**	**Flags**	**Window**	
Checksum			**Urgent Pointer**	
Options (optional)				

Figure 5. TCP header details.

Email, we want to know that these operations are successful. This guarantees that images and other web page content — as well as Email text and binary attachments — are received without error. Perhaps a better expression would be transferred without error.

If we receive some information and it has been corrupted, we simply ask for it to be retransmitted. This is the beauty of the TCP (Transmission Control Protocol) transport protocol within the TCP/IP suite of network protocols. TCP is a connection-oriented protocol where a session is set up between the transmitter and receiver (a client computer and a server computer).

Reliable exchanges of information are made possible through the use of acknowledgement messages sent back and forth between the transmitter and receiver. Figure 5 shows the various fields of the TCP protocol header. The header is a block of information contained in a network message that provides important information to the application processing the message.

One of the fields in the TCP header is the checksum field. This field stores a 16-bit number that is generated by adding all of the values represented by the TCP data together, ignoring any carries out of the 16th bit position. The 1s complement of the final sum is saved as the checksum. For example, if the sum was the 3C85 hexadecimal, the 1s complement checksum would be C37A hex.

When a TCP message is received, its checksum is recomputed by adding all of the received data plus the checksum. Typically, the result must equal the 0000 hexadecimal (2s complement checksum) or the FFFF hex (1s complement checksum). If the checksum does not match, a message is sent back to the transmitter indicating that the data must be resent.

The checksum — together with acknowledgement messages — allows us to exchange data reliably. Checksums are also used to verify the contents of a file or EPROM or the contents of a line of text in a file used for downloading. For example, here is a text file encoded using Intel's Hex record format:

```
:10200000310028D303DB03E680CA0520DB0
3E6109A
:0E201000C20320DB03E60F47D303DB03E68
0A9
:10201E00CA1A20DB03E610CA0320DB03D30
317170B
:0C202E001717E6F0B04FCD0E02C30320E0
:00000001FF
```

The last byte on each line (9A on the first line, FF on the last) is the 2s complement checksum byte. If you add all the bytes on each line together, you should always end up with 00.

Whether we use hardware or software, protecting our data is becoming more and more important. It is worth the time spent investigating these, and other, techniques for error detection and correction. **NV**

About the Author

James Antonakos is a Professor in the Departments of Electrical Engineering Technology and Computer Studies at Broome Community College. He has over 28 years of experience designing digital and analog circuitry and developing software. He is also the author of numerous textbooks on microprocessors, programming, and microcomputer systems. You may reach him at antonakos_j@sunybroome.edu or visit his website at **www.sunybroome.edu/~antonakos_j**

Approaching the Final Frontier

Near Space

Making a Light Sensor for the HOBO Data Logger

By using a photocell (CdS) as one element in a voltage divider, you can construct a simple light sensor. Because it uses a photocell, the light sensor's spectral sensitivity is very similar to that of the human eye. After you finish reading about how to build this light sensor for your HOBO data logger, I'll explain a very interesting finding about designing voltage divider-based sensors.

Any two resistors wired in series with a voltage source (battery) form a voltage divider. In the voltage divider, the voltage dropped across one resistor element is proportional to its resistance in sum with the second resistor element. The voltage drop across the resistor of interest is given by the following formula:

$$V_{drop} = V_{applied} \text{ X } (R_i / R_i + R_o)$$

In this formula, Ri is the resistor of interest and Ro is the other resistor.

By itself, the voltage divider circuit is not very interesting. However, things do get interesting when one element becomes variable and changes its resistance due to changes in some environmental condition. Now, by measuring the voltage drop across the variable resistor, you can measure the environmental variable of interest.

The cadmium sulfide (CdS) photocell is a light sensitive resistor. Its resistance decreases when exposed to bright light and increases when exposed to dim light. The photocell responds very quickly to changing light conditions, but not as fast as a phototransistor or photodiode.

You will need the following components to make a CdS light sensor for your HOBO data logger:

- Cadmium sulfide cell (My particular cell has a resistance that ranges from 100 Ω in bright light to 20K in the dark.)
- Fixed resistor (A 1/4 watt resistor is sufficient.)
- 3/32" stereo jack kit
- Thin heat shrink tubing
- #24 AWG stranded wire (preferably three colors, to keep the wires differentiated)

Note: The value of the fixed resistor depends on the resistance range of the CdS cell. For my light sensor, I used a 1.5K resistor. At the end of this article, I'll explain how you can determine the best resistor value for your particular CdS cell.

Each input to the HOBO is through a 3/32" stereo jack. The stereo jack has three contacts: tip, ring, and base. Voltage to operate the sensor comes from the tip. The signal to be digitized is connected to the ring of the stereo jack and the ground is connected to the base. The diagram in Figure 1 illustrates the connections.

I placed the fixed resistor close to the stereo jack and ran a long extension out to the CdS cell. I decided to keep the fixed resistor close to the HOBO to minimize the amount of wire my sensor needed. Note that the HOBO is digitizing the voltage drop across the CdS cell because the ground is connected to one end of the CdS cell and the signal is connected to the other end.

Figure 2. The completed light sensor — minus the ping pong ball.

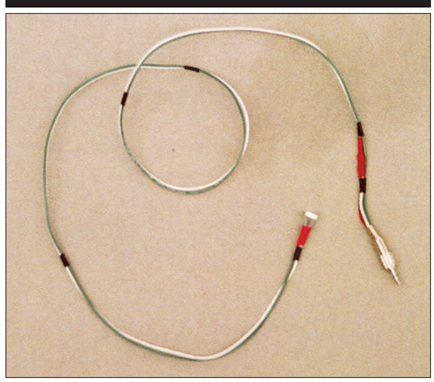
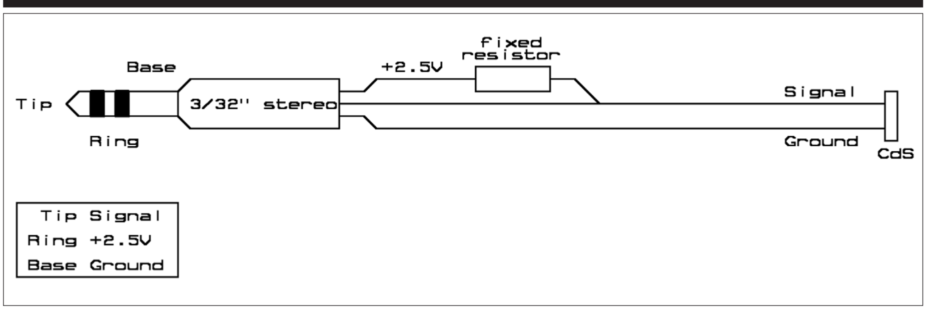


Figure 1. CdS light sensor diagram.



CdS						
	1,000	1,200	1,400	1,600	1,800	Fixed
100	= 2.5*[$A$3/($A$3+B2)]					
20,000	= 2.5*[$A$4/($A$4+B2)]					
Range	= +B4-B3					

Table 1

Lay out the components of the light sensor on a table. Be attentive to the fact that you may want to locate the light sensor some distance from the HOBO. This allows you to store the HOBO well inside the near spacecraft (NS craft), where it will remain warmer and still be able to expose the CdS cell to the elements. In my light sensor, I made the cable two feet long.

I'll refer to red wire for 2.5 volts, white for signal, and green for ground. Adjust my directions for any color changes in your light sensor. Cut the wires to length and strip about 1/4" of insulation from one end of each wire. From the remaining ends of the wires, you can strip 1/2" of insulation. Twist the strands of the wires and tin them. The short ends of the wires are soldered to the 3/32" stereo jack. The red wire goes to the tip, the white wire to the ring, and the green wire to the base. There's not a lot of room to work on the stereo jack, so work slowly and avoid shorting it out. After soldering the wires to the stereo jack, use a DMM to ensure there are no shorts.

Cut the leads of the fixed resistor and CdS cell to about 1/2" and tin the leads. Slide a length of heat shrink tubing over the red wire. Hold the red wire against one lead of the fixed resistor and heat both wires with a soldering iron. Solder will flow from the tinned lead and wire, soldering them together. Let the solder cool and cover the connection in heat shrink. Repeat this process with the green wire and one lead of the CdS cell.

Determine where the fixed resistor will solder to the signal wire. At that point in the white wire, use wire strippers and cut a 1/2" band of insulation. You'll need to use a sharp Exacto knife to remove the band of insulation from the wire. Do this carefully or your light sensor will suffer from nicks. Slide a larger diameter heat shrink over the resistor and the area where it solders to the signal wire.

Slide a short length of thin diameter heat shrink over the white wire and solder the remaining end to the free lead of the CdS cell. At this point, your light sensor is complete. However, there is a problem with the current design. The CdS is sensitive to its pointing direction. This may not be a problem in some cases, but, when you want to measure the brightness of the sky, it becomes a problem when the NS craft rotates the CdS cell into and out of the sun. Here's my solution to this problem.

A photographer's light meter records the average light background by using a diffuser. The diffuser is a hemisphere of white plastic (glass?) covering the light-sensitive element of the light meter. After giving it some thought, I concluded that a ping pong ball can make a great diffuser. So, I used an Exacto knife to drill a small hole in the surface of a ping pong ball. I made sure to drill the hole through the portion of the ball that was stamped with lettering.

This left the rest of the unmarked ping pong ball to diffuse sunlight. The hole I drilled was made just large enough to admit the CdS cell. After placing the CdS cell just inside the ping pong ball, I glued it into place with hot glue. The final product reminds me of a large eyeball with a copper-based optic nerve. In one of my NS missions this year, I plan to dangle the eyeball from beneath the bottom module of the NS craft and record the voltage across the CdS cell.

Calibration

I have yet to find a data sheet explaining how the resistance of a typical CdS cell varies according to light intensity. Eventually, I'll experiment with the light sensor to find out. I'll record the voltage drop across the CdS cell in a dark room as I bring a light source closer to the eyeball. Remember that light intensity drops off as $1/r^2$. So, when the light source is brought to one half the distance away from the sensor, the light intensity increases by a factor of four.

In my spreadsheet, I'll record the voltage drop across the CdS cell and the distance of the light source. Distance will then be converted into intensity by the formula, 1/(distance * distance). In the next column of the spreadsheet, I'll convert intensity into relative intensity by dividing each intensity by the intensity at the greatest distance. Then, I'll graph the CdS voltage and relative intensity.

I can generate an equation from the graph and use it to analyze the changes in brightness as a function of altitude during an experiment. In a future column, I will explain how to create an equation from discrete values such as these and how to

Near Space Seeds Project (NSSP)

My NS mission of 21 March 2004 carried four sets of seeds to an altitude of 85,140 feet. I want to share these seeds with elementary school students as part of a science experiment. I hope this will be a long term project, where students plant the seeds, keeping each group of plants isolated from the other groups.

After the plants go to seed, students will collect the seeds, document the group to which they belong, and return them for another flight into NS. After the mission, the seeds will be returned to the students for planting and seed harvesting. Perhaps, over many generations, variations between the groups due to the differences in their exposure will begin to show up.

Table 2 explains the difference between the seed groups in each set.

Note: This first set of exterior exposed seeds was stored in a plastic bag suspended outside the NS craft.

If you're a teacher who is interested in being a part of this experiment and you can carry out the following procedure, please contact me at the Email address in the About the Author box. I will send one set of seeds to the first four teachers to contact me. There is no charge for participating. More seeds will be launched in future flights, so there will be more opportunities.

Procedure

1. Find a location with sunlight and air for the plants.

Note: Remember, you need to plant three groups of seeds and there needs to be enough space between the groups to prevent them from cross-pollinating plants from a different group.

2. Prepare planters for the seeds and document your materials.

Note: You will need to use identical procedures for future generations of seeds.

3. Water and feed the groups identically.

Note: The only difference should be the seeds' level of NS exposure.

4. Document plant growth in each group.

Note: Suggested characteristics to document include (but are not limited to) the following:

A. Number of days to germination.
B. Percentage of seeds that germinate.
C. The average height of plants over time.
D. Average number of leaves per plant.
E. Number of days until flowers form.
F. Average number of flowers per plant.
G. Number of seeds produced per plant.

If the class is mathematically inclined, they can also calculate the standard deviation for each measurement. Also note that a digital camera comes in handy.

5. Erect a barrier between the seeds.

Note: It's *critical* that plants from different groups don't pollinate each other.

6. Harvest seeds from several plants in each group and prepare them for another flight into NS.

Note: It would be best if the seeds are placed inside a clean, dry test tube and covered with a small cotton ball. The test tube is then covered with a stopper containing a hole. The hole lets air out of the test tube during the flight without popping the stopper off. The cotton is to keep the seeds from spilling during the flight, especially during the rough descent and landing.

7. Label each test tube with the group that the seeds belong to (control, interior, or exterior).

* Note: Write the group name on a small piece of masking tape and stick it to the test tube. For added security, cover the writing on the tape with clear tape. This will keep the name from rubbing off during handling. Place the name near the top of the test tube where it cannot protect the exterior seeds from exposure to UV during the mission.

8. Through Email, arrange for the seeds to go up on the next available flight.

Note: If you send the seeds through the mail, carefully pack them in a cardboard box for shipping. The test tubes should be packed so that they cannot bang against each other and break.

9. Each test tube of seeds will be placed where they were on previous flights.

Note: After recovery, the seeds will be returned for planting and the procedure repeats over again.

On a final note, you can purchase your own seeds for a flight into NS. Please contact me first, however, so I can schedule a flight for your seeds. It would be best if classes from the same school sent their seeds in single test tubes and divided up the seeds after they are returned. Sharing room in the same test tube will simplify scheduling.

Name of Group	Location of Group	Minimun Pressure Experienced	Minimum Temperature Experienced	UV Exposure	Maximum Cosmic Ray Count
Control	Left on ground	Sea level (1,013 mb)	Room temperature	Not significant	Approximately 4 CPM
Interior	Inside near spacecraft	3% sea level (30.5 mb)	-30 degrees Farenheit	Not significant	Approximately 700 CPM
Exterior	Outside near spacecraft	3% sea level (30.5 mb)	-70 degrees Farenheit	Significant *	Approximately 700 CPM

Table 2

calculate the quality of the resulting equation.

Best Fixed Resistor Value

How did I determine the best value for my fixed resistor? I considered the best fixed resistor value to be the one that generates the greatest range of voltage drops across the variable resistor.

Initially, I created a spreadsheet and calculated the range of voltage drops across the variable resistor. The spreadsheet has four rows and seven columns. The rows contain the expected maximum and minimum values of the variable resistor. The columns contain the several fixed resistor values that I'm testing. The spreadsheet calculates the range of voltages I can expect from the variable resistor. After looking at the results, I changed the fixed resistor values in the columns and updated the spreadsheet. With every iteration, I was homing in closer to the optimum fixed resistor value.

The spreadsheet equations I used are shown in Table 1. Copy and paste the first row of equations into the cells of the remaining rows.

Juggle the fixed resistor values and rerun the spreadsheet until you find the fixed resistor value yielding the greatest voltage range. Now, you would think there must be a better way to do this. In fact, I found one.

I swim for exercise. The problem with swimming — besides chilly pool water — is that the scenery never changes. This gives you lots of time to think about things. One day in early February, I was thinking about the difference between arithmetic and geometric means and, for some inexplicable reason, it dawned on me that one of these means might be useful in determining the best value for a fixed resistor in a voltage divider. For those readers who are fuzzy with their math, here's short definitions of arithmetic and geometric means.

For calculating the best value for a fixed resistor, I'm only interested in calculating a mean from two numbers, so my definitions use only two values (you can calculate means for more than two numbers). The arithmetic mean is the result when you add two numbers together and divide the resulting sum by two. The arithmetic mean is the number that is equally far from either of the two numbers used to calculate it. So, the arithmetic mean of the numbers 4 and 8 is 6, which is the same distance away from both numbers.

The geometric mean of two numbers is the number that is an equal *factor* away from both numbers. As an example, the geometric mean of 2 and 32 is 8. The number 8 is four times higher than 2 and 32 is four times higher than 8. How do you calculate the geometric mean of two numbers? To calculate it, multiply the two numbers in question and take the square root of the result. In the above example, you get, 2 x 32 = 64 and the square root of 64 is 8.

When I got back home, I fired up the old PC and pulled up my Excel spreadsheet. Sure enough, the maximum voltage range in a voltage divider is generated when the fixed resistor is the geometric mean of the maximum and minimum range of the variable resistor.

I was amazed when I saw this. Why should this be the case? I don't know why at this time, but I tried to visualize a mathematical solution based on a square with the same volume as any given rectangle. The sides of that square are the geometric mean of the sides of the rectangle. So far, though, I have come up empty-handed.

If a reader can provide a proof that the geometric mean always generates a maximum voltage range of the voltage divider, I'll give credit in this column and send a memento that has been carried into near space. This offer is only for the first proof Emailed to me at nearspace@yahoogroups.com

Good luck and thanks for your efforts.

Onwards and Upwards, Your Near Space Guide **NV**

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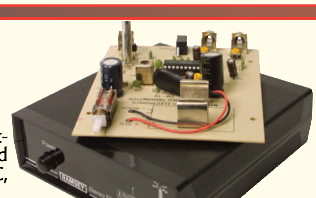

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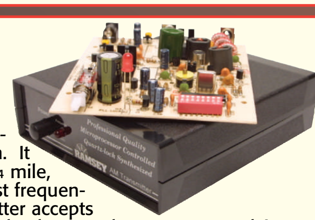
- ✔ Settable pre-emphasis 50 or 75 µSec for worldwide operation
- ✔ Line level inputs with RCA connectors

The FM10A has plenty of power and our manual goes into great detail outlining all the aspects of antennas, transmitting range and the FCC rules and regulations. Runs on internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter is also available. Includes matching case!

FM10C	**Tunable FM Stereo Transmitter Kit**	**$44.95**
FMAC	**110VAC Power Supply for FM10A**	**$9.95**

Professional Synthesized AM Transmitter



- ✔ Fully frequency synthesized, no frequency drift!
- ✔ Ideal for schools
- ✔ Microprocessor controlled

Run your own radio station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. Broadcast frequency is easily set with dip-switches and is stable without drifting. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!

AM25	**Professional Synthesized AM Transmitter Kit**	**$99.95**

Tunable AM Transmitter

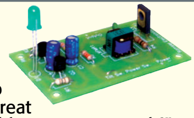
- ✔ Tunes the entire 550-1600 KHz AM band
- ✔ 100 mW output, operates on 9-12 VDC
- ✔ Line level input with RCA connector

A great first kit, and a really neat AM transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! One of the most popular kits for schools and scouts! Includes matching case for a finished look!

AM1C	**Tunable AM Radio Transmitter Kit**	**$34.95**
AC125	**110VAC Power Supply for AM1**	**$9.95**

Mini-Kits... The Building Blocks!

Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC

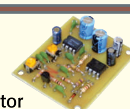
TS4	**Tickle Stick Kit**	**$12.95**

Super Snoop Amplifier

Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9	**Super Snoop Amp Kit**	**$9.95**

Dripping Faucet



Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

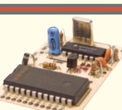
EDF1	**Dripping Faucet Kit**	**$9.95**

LED Blinky

Our #1 Mini-Kit for 31 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Runs on 3-15 VDC.

BL1	**LED Blinky Kit**	**$7.95**

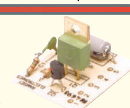
Touch Tone Decoder



Strappable to detect any single DTMF digit. Provides a closure to ground up to 20mA. Connect to any speaker, detector or even a phone line. Runs on 5 VDC.

TT7	**DTMF Decoder Kit**	**$24.95**

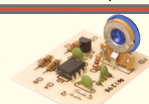
Electronic Siren



Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

SM3	**Electronic Siren Kit**	**$7.95**

Universal Timer



Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5	**Universal Timer Kit**	**$9.95**

Voice Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

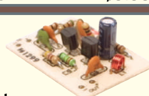
VS1	**Voice Switch Kit**	**$9.95**

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to 100 mA.

TD1	**Encoder/Decoder Kit**	**$9.95**

RF Preamplifier



Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7	**RF Preamp Kit**	**$19.95**

Touch Switch

Touch on, touch off, or momentary touch hold, your choice! Uses CMOS technology. Runs on 6-12 VDC and drives any load up to 100 mA.

TS1	**Touch Switch Kit**	**$9.95**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Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

GUI on a Beam of IR

Wireless doesn't always mean RF ...

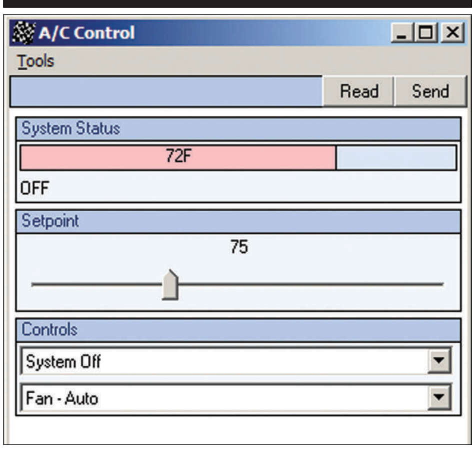
If you ask my close friends, they'll tell you that I'm as stubborn as a mule, yet I maintain the right to be human; therefore, the right to be wrong. I'd like to think that, when I am wrong, I admit it — I try, anyway.

When the FlexiPanel first came out a few months ago I looked at it — for about two seconds — and thought it was wholly uninteresting. It turns out I was wrong; it's actually a very clever device. I think what originally put me off was that I *assumed* I'd have to develop a GUI for my Pocket PC with traditional tools. While that's not too hard, it's certainly not as easy as developing a desktop application. This is especially true when one needs to access serial communications ports (this includes IR). Well, again, I was wrong because I just didn't give the FlexiPanel a fair look the first time through. Let me correct that.

Beam Me Up, GUI

It turns out that we don't have to develop software for our Pocket PC after all — that's already been done for us in the form of the FlexiPanel client software (called VCP for *Virtual Control Panel*). So what gives? Well, here's what I didn't originally understand: The VCP acts like a specialized browser for the FlexiPanel module and it's actually the FlexiPanel module that beams the GUI to the VCP that runs on our Pocket PC. That's pretty cool and a very clever idea.

Figure 1. VCP in Windows.



What this means is that we could have multiple devices using FlexiPanel modules and not have to worry about separate apps for each one on our Pocket PC. Imagine what a hassle the Internet would be if we needed a separate application for every website we visited.

In fact, the workflow to use the FlexiPanel is about the same as that for creating and publishing a website on the Internet. The first step isto create a script file that will produce the desired output in the browser application. That file is uploaded tothe server — in our case, to the FlexiPanel module. A client request will cause the file to be downloaded anddisplayed to the client. Sophisticated web pages will allow the user to provide information to the server through the interface; so does the FlexiPanel VCP.

So, where does the BASIC Stamp microcontroller fit in? Its purpose is to serve as the host for the FlexiPanel module. As the host, it can send information to the module that can be displayed in the VCP and it can also read information from the module (that was provided by the VCP) and is required by its application.

Man, It's Hot!

Summers in North Texas are hot and humid — there's no getting around it. That being the case (and the temperature on my mind), let's demonstrate the FlexiPanel system by creating a handheld UI for an air conditioning controller. I used my own home AC controller as the model for the project. Here are the requirements:

- Display current temperature
- Display current status
- Set/Display temperature setpoint
- Set/Display operating mode
- Set/Display fan mode

Application logic and control outputs are provided by the BASIC Stamp. It also reads the current temperature from the DS1621 (I2C version of our old friend the DS1620). Since we're using the VCP, we don't have a local display — but we could add one later if we choose to, since there are plenty of I/O pins left when we're done with this project.

Creating the GUI is probably the trickiest aspect of the whole deal. After experimenting with some of the FlexiPanel examples (there are plenty of screen shots in FlexiPanel.PDF on **www.hoptroff.com**), you'll get a good idea of how the VCP handles the various interface controls. Once you're comfortable with what it does, sketch your interface and work out the details before starting the GUI script. Let me work backward and show you the final output before you see the script that develops it.

Take a look at Figure 1. As you can see, all of the requirements for the controller specified earlier are nicely handled by the VCP software. The screen shot is actually from the Windows version of the VCP that is used in development and testing. Once the program is ready to go, it can be downloaded (via IrDA link) to the VCP on a Pocket PC. Figure 2 shows our AC controller interface running on an HP iPaq.

It All Starts With a Script

Just as cool websites are based on a script (HTML file), the VCP GUI is created with a simple script. Let's have a look at the script that generates the UI for our AC controller.

We start with a header that provides device and connection information:

```
PARTNUM          irGUI452M
DEVICENAME       "A/C Control"
SERIAL           RANDOM
RESET
UNASSIGNED_PINS_OUTPUTS

I2C              0x68
I2CADDRESSING    1BYTE_INDEX
```

The PARTNUM parameter describes the device that will hold the GUI information. In our case, we're using the pre-built module, which has a part number of `irGUI452M`. DEVICENAME identifies the FlexiPanel module for the VCP (this text will appear in the VCP title bar) and for other devices that are capable of IrDA communications (like our PC).

The SERIAL parameter describes how the serial number is generated for the device. The reason for the serial number is to prevent conflicts between devices that are running the same application code. I used `RANDOM` for this project. Other options for SERIAL are `INCREMENTAL` and manual (user-supplied four-byte serial number). If we have two devices that serve the same function and we want to exchange information between them (read from one and send to the other), we'll need to match the serial numbers. The easiest way to do this is to provide the four-byte serial number manually.

The next line tells the VCP to RESET after it's configured. This will make sure that all values are initialized properly. The onboard controller has extra I/O pins and, for the

Figure 2. VCP on an iPaq.

module, we need to tell them to be set as outputs (UNASSIGNED_PINS_OUTPUTS) to reduce current consumption. If using the FlexiPanel irGUI processor in a specialized app,

the extra pins may be handled differently.

The next section in the header has to do with connecting to a host controller — in our case, the BS2p. The connection between the host and the FlexiPanel module is via I2C at the address specified by the I2C parameter. The default (read) address for the FlexiPanel module is 0x68, but we can specify any even address between 0x68 and 0xFC.

The final parameter is called I2CADDRESSING. This specifies how we will address the various controls in the VCP. I think for most applications that `1BYTE_INDEX` is going to be the easiest to deal with — as long as we plan our project and then work the plan. Using this method, each control in the VCP is accessed by its position in the definitions discussed shortly and using one byte gives us the ability to deal with up to 256 controls. This method is also the cleanest to implement using **I2CIN** and **I2COUT**.

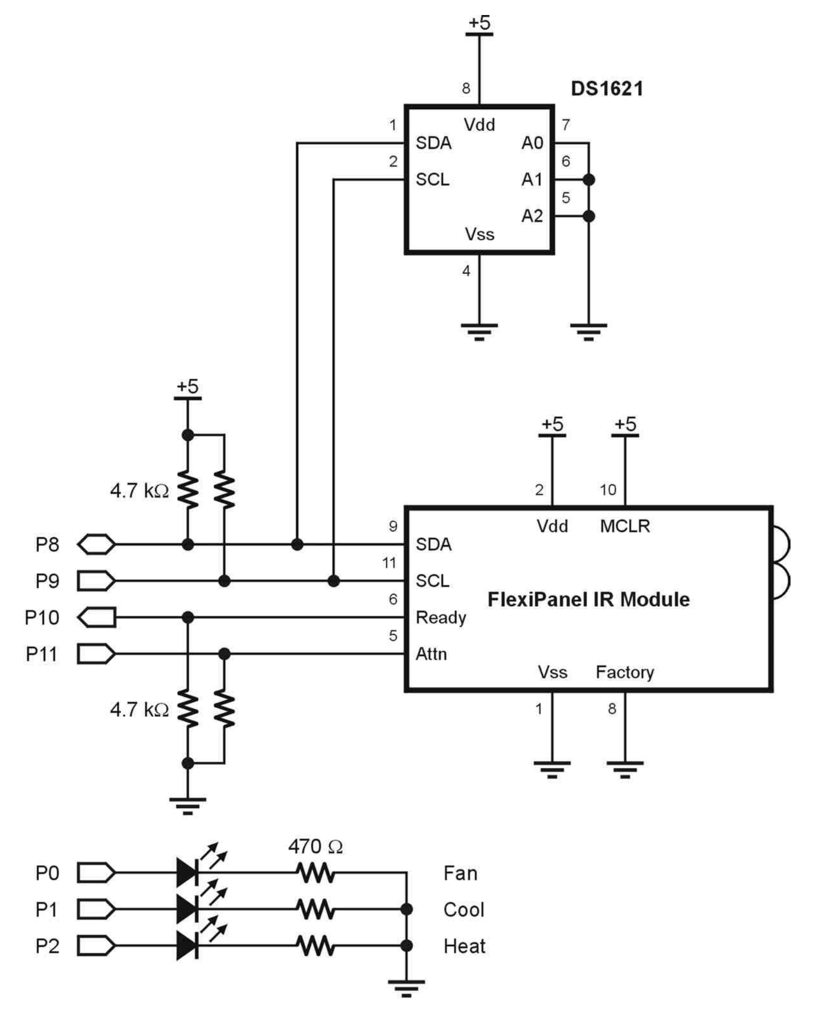
Give Me Some Control

Okay, now we can get into the fun stuff — the VCP controls. If you look at the screen shots included in the documentation, you'll notice that the controls are always stacked vertically in the VCP window. This strategy keeps the controls' scripting very simple; controls will appear on the form in the order defined.

Going back to our requirements, the first thing to display is the current temperature. We have a few choices here, but, this being a temperature controller, using a numeric output in the form of a progress bar (which suggests a mercury thermometer) seemed the logical choice. Here's the script for this control:

```
CONTROL NUMBER
    ID          ctmp
    FIXEDSTORE  ROM
    VARSTORE    RAM
    STYLE       FIXED
    OPTION      PROGRESS
    TITLE       " System Status"
    UNITS       "F"
    VALUE       72
    CTL_MIN     0
    CTL_MAX     100
```

Figure 3. AC controller schematic.



The type of control we'll use for the current temperature is the NUMBER type. There are options to display numbers, but, as we just discussed, we're going to use the `PROGRESS` type. This STYLE is also set to `FIXED`, which means it cannot be changed by the user running the VCP, though it can be changed by the host. The UNITS parameter allows us to display a string after the value and CTL_MIN and CTL_MAX allow us to specify the control's value range.

All controls must have a unique, four-byte ID. I chose to use a four-byte string to serve as a reminder (that matched with constants in the PBASIC host program), but any unique four-byte value will work. The FIXEDSTORE and VARSTORE parameters specify the location of fixed (like the control's title) and variable (like the value) data that are stored in the module. The parameters we used are typical, though there are other options.

All VCP controls are surrounded by a grouping box, even when there is just one control. This box has a title string that is specified by the TITLE parameter. We can group controls into the same box and we'll demonstrate that in just a moment.

Our next control is a TEXT type to display system status. The status text will tell us what's actually going on inside our AC controller (OFF, Idle, Cooling, Heating, etc.). We give it a maximum length with the MAXCHARS parameter and, in this case, we are grouping it into the "System Status" box

by using APPEND.

```
CONTROL TEXT
    ID          stat
    STYLE       FIXED
    FIXEDSTORE  ROM
    VARSTORE    RAM
    VALUE       "OFF     "
    MAXCHARS    8
    APPEND
```

Now, we get to the controls that we'll actually change and will have an effect on our control program. The first is the temperature setpoint. The controller logic will use this setpoint — along with the operating mode and current temperature — to determine which control outputs, if any, are active.

```
CONTROL NUMBER
    ID          setp
    STYLE       EDIT
    OPTION      SLIDER
    FIXEDSTORE  ROM
    VARSTORE    RAM
    TITLE       " Setpoint"
    VALUE       75
    CTL_MIN     65
    CTL_MAX     95
```

Notice that the setpoint is (logically) a NUMBER control, but this time it is formatted as a `SLIDER` and its STYLE is set to `EDIT` so we can change the value.

The next two controls mimic the slide switches on my home AC controller. Both are SELECTION controls that use the `DROPDOWN` option. This makes them look and behave like a standard Windows dropdown selector. The VALUE parameter selects the current position of the SELECTION control. The ITEM parameters provide strings for each available position in the control.

```
CONTROL SELECTION
    ID          mode
    OPTION      DROPDOWN
    FIXEDSTORE  ROM
    VARSTORE    RAM
    VALUE       0
    TITLE       "Controls"
    ITEM        "System Off"
    ITEM        "Cool"
    ITEM        "Heat"

CONTROL SELECTION
    ID          fctl
    OPTION      DROPDOWN
    FIXEDSTORE  ROM
    VARSTORE    RAM
    VALUE       0
    ITEM        "Fan - Auto"
    ITEM        "Fan - On"
    APPEND
```

Okay, now that we have a VCP script, it's time to give it a run. Let me encourage you to test the VCP in a stand-alone manner before adding any host (BASIC Stamp) interaction with the FlexiPanel module. If you decide to make changes in your VCP script, be sure to remove the host program so that it doesn't interfere with your FlexiPanel module reprogramming. This is not as tedious as it sounds and will save you a bit of trouble as you're refining your FlexiPanel projects.

After connecting the circuit shown in Figure 3, make sure that the BASIC Stamp is "blank" — that is, there is no program running that attempts to access the FlexiPanel module. The easiest way to do this is to download the following single-line program:

```
END
```

After the circuit is powered up, bring it into range of your PC's IrDA port. If you don't have an IrDA port built into your PC, for about $30.00, you can get an IrDA adapter that plugs into a USB port — that's what I did and it works great.

Once the PC acknowledges the presence of the FlexiPanel module, start the program called **FlexiPanelConfig** and then click the "Read Script" button. A standard *File Open* dialog will be displayed. Select the desired script (.rs file) and click the "Open" button. If all goes well and there are no errors in the script, you'll see an

information dialog like the one in Figure 4. Click on the "Program" button to download the script data to the FlexiPanel module. Note that there are no status or completion messages provided by the configuration software. Leave the mouse pointer over the program dialog until it changes from an hourglass back to an arrow (standard pointer) before proceeding.

Now we can test it. Start the program called **FlexiPanel IR**. The working space will initially be blank. Click on the "Read" button and, after a brief delay, the title and controls will appear, as shown in Figure 1. Play with the controls to see how they work and note that it really wasn't very difficult to create a nice, functional display. Keep in mind that we're just barely scratching the surface of the capabilities with the VCP software.

The Host With the Most

Our host will, of course, be the BASIC Stamp microcontroller — but if you have something else that is capable of I2C communications, you can use it; you'll just need to adapt the code here for your target.

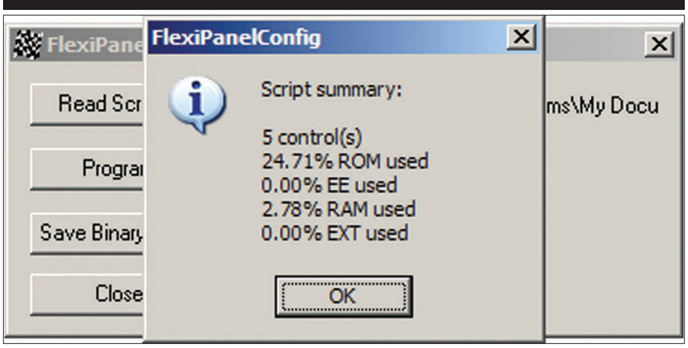
For this project, the BASIC Stamp has three tasks:

1. Read the current temperature from DS1621.
2. Exchange data with FlexiPanel module.
3. Process and update control outputs.

Okay, first things first. This is a temperature controller we're building, so reading the current temperature is a priority. The DS1621 was selected so that we could take advantage of the I2C bus that is required by the FlexiPanel module.

```
Get_Temperature:
  I2COUT SDA, Wr1621, [RdTemp]
  I2CIN  SDA, Rd1621, [tempIn.BYTE1, tempIn.BYTE0]
  tempIn = tempIn >> 7
  ' Celsius
  tempC = (tempIn / 2) | ($FF00 * sign)
  ' Fahrenheit
  tempF = (tempIn | ($FF00 * sign)) + 110
  tempF = tempF * 9 / 10 - 67
  RETURN
```

Figure 4. VCP script loaded and ready for VCP.



As you can see, this is pretty straightforward. We start by sending the RdTemp instruction then read back the current temperature. The value returned by the DS1621 will be in units of 0.5 degrees Celsius and will be shifted left in the *tempIn* word. Shifting everything to the right by seven bits takes care of the alignment. Conversion to Celsius is really just a matter of removing the half-degree bit, then correcting the upper bits of the *tempC* value if the temperature is negative (sign bit will be 1 when negative).

Converting to Fahrenheit uses an old Scott Edwards trick from the DS1620, which starts by converting the temperature to an absolute value. By doing this, we maintain the proper two's compliment format for negative numbers. If you decide to add **DEBUG** or a local display, be sure to use the SDEC modifier, in the event the temperature is negative. (You must live in an igloo if it is!)

With the current temperature in hand, we can send it to the FlexiPanel module and receive any controls or setting changes that may have happened since the last access.

```
Process_FlexiPanel:
  HIGH Attn
  DO : LOOP UNTIL (Ready = IsHigh)

  I2COUT SDA, WrFlxPnl, CTmp, [tempF.BYTE0,
                                      tempF.BYTE1]
  INPUT SCL
  DO : LOOP UNTIL (SCL = IsHigh)

  SELECT status
    CASE StatOff
      I2COUT SDA, WrFlxPnl, Stat, ["OFF     ", 0]

    CASE StatIdle
      I2COUT SDA, WrFlxPnl, Stat, ["Idle    ", 0]

    CASE StatCool
      I2COUT SDA, WrFlxPnl, Stat, ["Cooling", 0]

    CASE StatHeat
      I2COUT SDA, WrFlxPnl, Stat, ["Heating", 0]

    CASE StatFan
      I2COUT SDA, WrFlxPnl, Stat, ["Fan     ", 0]
  ENDSELECT
  INPUT SCL
  DO : LOOP UNTIL (SCL = IsHigh)

  I2CIN SDA, RdFlxPnl, StPt, [setPoint]
  I2CIN SDA, RdFlxPnl, Mode, [sysMode]
  I2CIN SDA, RdFlxPnl, FCtl, [fanCtrl]

  INPUT Attn
  RETURN
```

Even though the exchange between the BASIC Stamp and the FlexiPanel module is via I2C, we must first get the module's attention before initiating any communication. This is accomplished by taking the Attn

pin high. When the module is available, it will set the Ready line high.

The first piece of information transmitted is the current temperature. Remember that the current temperature control in the VCP was first; hence, it has an index value of 0. When we address controls in the VCP, the address used by **I2CIN** and **I2COUT** will be the control index (0 – n). This keeps us from having to know the location of data within the module.

Storing the temperature may take a moment, so we'll monitor the clock (SCL) line. The FlexiPanel module uses "clock stretching" (pulls the clock line low) to indicate that it's busy, so waiting for the clock line to go high before moving to the next control is a good idea after each write.

The next control is the current system status text. For me, the cleanest implementation was the use of the **SELECT-CASE** structure. To be honest, I'm not a big fan of this structure for embedded control (it's a code hog), but, in this case, it just makes good sense. Note that each string is terminated with a 0 — this is a requirement of the VCP.

Next, we read in the setpoint, mode, and fan controls from the VCP.

At this point, all the information has been exchanged, so we can release the module and apply the air conditioning logic.

The processing logic is very simple. We start by checking the mode, and if it's in an active mode (cool or heat), check the current temperature against the setpoint. Here's a case where you might be inclined to use **SELECT-CASE**, but there is so much code involved that it can become a bit unwieldy. No problem — **BRANCH** works really well here.

```
Process_Temp:
  BRANCH sysMode, [System_Off, Cool_On, Heat_On]

System_Off:
  IF (fanCtrl = FanAuto) THEN
    status = StatOff
    Fan = IsOff
  ELSE
    status = StatFan
    Fan = IsOn
  ENDIF
  Cool = IsOff
  Heat = IsOff
  RETURN
```

As you can see, **BRANCH** selects the code segment that corresponds with the operating mode. Off is the easiest to deal with; turn off the control outputs — unless the user has placed the fan in manual mode for circulation.

The logic for cooling and heating is identical, so we'll just look at cooling. Really, this code is so easy that I didn't even put comments in my original listing.

```
Cool_On:
  IF (tempF > setPoint) THEN
    status = StatCool
    Fan = IsOn
    Cool = IsOn
    Heat = IsOff
  ELSE
    GOTO Manual_Fan
  ENDIF
  RETURN
```

It should make perfect sense: If the temperature is above the setpoint, turn on the fan and cooling control outputs, otherwise jump to the Manual_Fan section. Let's have a look at that.

```
Manual_Fan:
  Cool = IsOff
  Heat = IsOff
  IF (fanCtrl = FanOn) THEN
    status = StatFan
    Fan = IsOn
  ELSE
    status = StatIdle
    Fan = IsOff
  ENDIF
  RETURN
```

This code turns off the cooling and heating control outputs and then checks the fan control setting for automatic or manual mode. If the fan has been set to manual, it gets activated. The status called "idle" indicates that cooling or heating is selected, but, at the moment, the system is at rest.

Okay, I have run myself out of space, but let me finish with this. The FlexiPanel is a very unique device and can add a sophisticated user interface to embedded projects by using the Pocket PC you may already own. Be sure to download all of the documentation and examples and spend some time with them. As you'll see, there's a whole lot more that can be done than we did here — some really fun stuff. We'll be back at this next month with a Bluetooth version of the FlexiPanel. It brings additional features and removes the requirement to be right on top of the embedded device.

Until then, Happy Stamping. **NV**

Additional Resource

Société HOPTROFF — **www.hoptroff.com**

Jon Williams
jwilliams@parallax.com
Parallax, Inc.
www.parallax.com

Circle #75 on the Reader Service Card.

The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Printed Circuit Board Layout

A Printed Circuit Board (PCB) is more than just traces that connect components together. It is an integral part of any design. A good PCB design is one that you never notice. A bad design can cause headaches for years.

Fundamentals

Basically, a PCB is an insulating base material containing copper traces. The insulating material is typically epoxy fiberglass. Less expensive phenolic is sometimes used where performance is not critical. For special cases, teflon and ceramic bases are employed. Occasionally, there are other materials, but that's rare. The standard base thickness is typically 1/16" (or 0.062"). However, small boards (a few inches square or less) may have a reduced thickness.

The vast majority of PCBs made in the US start with a solid copper side that is well bonded to the base material. The thickness of the copper is designated by "ounce." This refers to the weight of one ounce of copper spread over one square foot. "One ounce" copper plating is about 0.003" thick. Two ounce copper is 0.006" thick, etc.

The desired traces are printed onto the copper in some manner (to be discussed in more detail later) with a material called "resist." The board is then placed in a chemical bath that dissolves — or etches — all of the copper not covered by the resist. The chemicals most often used by hobbyists are ferric chloride and ammonium persulphate.

Commercial PCB fabricators generally use different chemicals that are cheaper, like ammonium chloride. They heat the bath and add catalytic agents to improve performance. After washing and cleaning the etched board, the result is a copper circuit pattern on an insulating base — a printed circuit board.

Layers

Before Surface Mount Technology (SMT) arrived, there were two designated layers: the component side and the solder side. These are self-explanatory with standard through-hole components. Since SMT allows components to be placed on two sides, these designations have become "top" and "bottom," but the older terms are still widely used. The convention is that all layouts are viewed from the top side. This makes the bottom layer similar to an X-ray. You see it through the insulator. The result is a mirror image with left and right reversed. This can be very confusing if you are not aware of it.

There are also two additional types of "layers" that are not real layers — these are the "silkscreen" layer and the "solder mask" layers. The silkscreen layer is an aid to assembly and troubleshooting. It's just text (with occasional, simple graphics) that identifies each component and its orientation. A good silkscreen can save tremendous amounts of production and repair time during manufacturing.

The solder mask is used to control where the solder is applied to the PCB traces. You only want solder to connect the components to the solder pads. You don't want solder on all of the other traces. Again, this is very useful during manufacturing. Hobbyists who make only one or two boards with a simple design don't really need a solder mask or a silkscreen.

Theory

Okay, so most of you know all that. Did you know that, at one time, all PCBs had only a single side of traces? Nowadays, the typical PCB has two trace layers (called a double-sided board). Complex boards — like motherboards — may have four to six layers (where each layer is insulated from the other by board material). There are some multilayer boards that have eight or more layers of traces. How many layers are necessary?

In theory, if you use only through-hole passive components and discrete transistors, a single layer is all that is necessary. Most RF boards have traces on only one side, although they use the second layer as a ground plane to improve performance. If you add standard-footprint DIP (Dual-Inline Package) opamps, you can still get by with a single layer. (I've never had to go to two sides.) This is because there is plenty of room for traces to pass between the leads of the passive components.

When you go to digital logic or other designs that use high pin-count chips, two trace layers are needed. When you have a chip with lot of pins in a fixed physical relationship, it is sometimes impossible to connect them to another chip with a different

layout without crossing (and shorting out). So, a second layer is required. In theory, only two layers are ever necessary.

You may need more than two layers for dense, highly populated boards — or for performance considerations. The "two layer" theory fails with dense boards because the parts are so close together and the traces and holes take up space, too. There simply isn't room for all the traces and holes and vias on two sides (vias are connections between one layer and another). If the density could be reduced, then the "two-layer" theory would work.

For high-speed or high-precision designs, more than two layers are used to improve performance. With four trace layers, the two middle ones are usually power and ground. This evens out the flow of power and reduces voltage fluctuations at different points on the PCB. The ground plane (one whole trace layer devoted to the ground) provides controlled impedance for high-speed signals. The close proximity of the ground and power planes acts as a capacitor to reduce noise.

Because two sides can be etched at a single time, the cost of a double-sided board is only slightly higher than that of a single-sided board. Multi-layer boards (more than two layers) are built up by laminating double-sided layers together. So, a four-layer board will cost about twice as much as a double-sided PCB and six layers are about three times as much. The PCB is often an expensive part of the design. If you use two layers and your competitor uses four, you have an edge.

Making Your Own PCB

Hobbyists have been making their own single-sided PCBs for decades. Double-sided boards are more difficult for two reasons. The first is called registration. The front and back layer have to be perfectly aligned — or registered — otherwise, a hole going through the pad on top may miss the pad on the bottom. For complex boards with close tolerances, this can be a significant problem.

The second difficulty for double-sided boards is the lack of plated through holes. A commercially produced PCB has the hole metalized to electrically connect the top and bottom pads. There is no way to do this without expensive equipment. So, hobbyists must solder both sides of a through-hole component (or connecting wire "via") for a proper connection.

There are several methods of making home-made PCBs. The most precise method is basically the same one commercial manufacturers use, which is photographic. The bare board is covered with a light-sensitive resist. The circuit pattern is copied to a film transparency. Then, the film is placed in contact with the sensitized board and exposed to light. The board is washed and only the resist exposed to the light remains. The board is then placed in the chemical bath to remove the copper. This method is usually too complicated and time consuming for most hobbyists. (There is also a procedure that uses a photographic negative transparency.)

The "iron-on" method is what most hobbyists use. Here, the circuit pattern is simply printed out (by a laser or ink jet printer) on a special film. Then the pattern is transferred from the film to the copper board with heat. An ordinary flat iron is commonly used. Great concept — unfortunately, the actual performance of this method is not always that good. Too little heat and the pattern doesn't stick to the copper. Too much heat and the pattern creeps, which can cause problems for traces that are close together. A colleague of mine gets great results with this method, but he has a special laminator for heating and uses a number of special techniques that he's developed over time. Perhaps this method just requires the proper touch — which I lack.

Finally, not all printers have precise paper-handling mechanisms. That is, the scale may not be exactly 1:1. A 2.5% scale error, which is not noticeable for printing, will cause a quarter inch size error in a 10 inch PCB. This is enough to foul up PCB mounting, cause problems with large PCB connectors, and create large headaches. (I know this from experience.)

There is also a technique that prints the pattern directly onto thin, flexible, copper sheets that feed into your printer. Then, you glue this to a base board and etch it. This eliminates the ironing step. (I haven't tried it.)

The technique that I prefer, unfortunately, is no longer generally available. It uses a pen-plotter to draw a special resist-ink directly onto the bare copper PCB. Then you etch it. It's accurate to the precision of the plotter (0.001" resolution for my plotter). Both the plotters and the ink are now very hard to get.

The last method is mentioned only for completeness; it can't be used by hobbyists. It's called "Multiwire" from Advanced Interconnection Technology (**www.ait-atlanta.com**). They don't use copper PC boards at all. They glue/embed thin, insulated wires into the base material. Because the wires are insulated, they can cross over each other without shorting. To make an electrical connection, a hole is drilled that cuts through the wire and exposes the copper end. Then, the hole is plated, which electrically connects the end of the wire to the metalized hole and the rest of the circuit. This method is very reliable and is used in some military applications.

Basic PCB Layout

For me, the first step in the physical layout of a PCB is a good schematic. With the exception of glue logic (discrete logic gates) and multiple opamp packages, I arrange the IC pins in physical order, as viewed from the top. I usually start with the IC that has the most pins and then place the other parts to create a visually simple schematic (if practical). This means only a few crossed lines. It's always easier to lay out a PCB with fewer crossed traces. This also creates a physical relationship between the schematic and the actual board, which is useful in troubleshooting.

I always place components and pads on a 0.100" grid, if possible. This makes calculations between the parts and case easy to figure. Basically, it's convenient. I also immediately identify the top and bottom layers with text "component side" and "solder side." The "solder side" text is mirrored (reversed left to right) because I see that layer from the top with my layout software. All software packages I know edit the bottom layer, as viewed from the top.

PCB board houses always want some identification of top and bottom layers. Otherwise, things really get fouled up. In the past, optical "targets" were added to aid in registration between sides and to provide focusing for the optics. More recently, this has been omitted. Round pads are standard. However, often pin 1 of an IC is identified with a square pad.

Trace Basics

The wider the traces and farther apart they are, the easier the board is to manufacture, the more reliable it will be, and the better its performance will be. Most PCB manufacturers can work with 0.007" traces and spaces. I use 0.020" traces and 0.015" traces when I can. This allows one trace between two DIP IC pins, which have a 0.050" pad. Trying to put two thin traces between 0.100" DIP pins always seems to lead to problems.

Thin traces are more fragile and have higher resistance than thick wires. They also handle less current. Here's how to estimate how much resistance it has and how much current a trace can handle: Remember that traces are about 0.003" thick for a standard PCB. So, you can calculate the cross-section area by multiplying by the trace width. A 0.020" wide trace has about a 0.060 square inch cross section area. Look this up in a wire-table and you will find that this is close to #32 gauge wire, which has a 0.063 square inch cross section. The table says that #32 wire has a resistance of 0.17 Ω per foot and can carry 90 mA (*The Radio Amateur's Handbook*, 1966).

These values are reasonably linear for different trace cross section areas. (Twice the area is half the resistance and twice the current, etc.) So, a 0.007" wide trace that has a 0.021 square inch cross section area can handle 30 mA and has 0.51 Ω/foot resistance. (Note: These current-carrying values are very conservative, which results in negligible heat generation. A 0.020" trace carrying about 2,000 mA causes a 10° C or 18° F increase in temperature.)

Traces that are close together are easier to short out and can electrically couple to each other. The traces act as antennas and capacitors. High speed digital lines next to high impedance analog lines are going to cause problems every time. Long traces are just as bad as long wires. They pick up noise and have appreciable impedance. Remember, even though your digital design only runs at 1 MHz, the state changes can cause transients into the GHz range.

Don't use acute angles in traces (more than 90°). This leaves a point that causes problems. First, it nearly acts like a one-turn inductor. More importantly, the point is not well supported and can easily lift. Obviously, it's not good to have your traces peeling off the PCB.

Using two 45° angles instead of one 90° angle will save space. This is especially true when you have a lot of traces running parallel to each other. The more space you can save, the smaller and less expensive the PCB will be. Don't forget — you pay for the PCB by the square inch (mostly).

Ground and Power

Proper grounding is critical. It's a topic that books have been written on. Obviously, I can only touch on the subject here. A ground and power plane are ideal, but often it's simply too expensive (it doubles the cost of the PCB).

I usually start with a wide ring (0.100" to 0.250") around the PCB that is my ground. This allows me to easily put large ground areas around the PCB mounting holes (which are typically near the edge of the PCB). That means that a star washer and a metal screw to the chassis make a good chassis-ground connection. It also means that ground traces only have to go to any board edge. This simplifies the layout. If there is any concern about ground loops (more than one ground current flowing in one conductor), I simply cut the ring.

In this way, I can control where and how the current flows in the trace. If the design is fairly simple, I'll spend extra time and try to make it single-sided and use the second side as a ground plane. There are always more connections to ground than to any other circuit node. Properly understanding how and where ground current flows in your layout cannot be overemphasized.

I use a similar ring technique for power, but on the other side. I carefully avoid the PCB mounting holes so that power/ground shorts will not occur. Running the traces back-to-back creates a small capacitor. This helps to reduce noise on the power line.

When I've finished the layout, I increase the width of the power and ground traces as much as I can. If there are large areas without traces, I'll fill them with solid copper connected to power or ground. More copper often helps and very rarely hurts PCB performance.

Surface Mount

Surface Mount technology (SMT) has added more facets to PCB layout. The parts are very small and the lead pitch (spacing between the centers of adjacent leads) can be very small. It's usually not possible to run any traces between the leads. This makes routing more difficult and increases the number of vias.

It's virtually impossible to use a single-side layout with high pin count SMT ICs. The pad sizes and shapes are different for different parts. You will need to refer to the manufacturer for these specifications. Testing and repair need to be considered more with SMT designs because it's hard to probe tiny, closely-spaced pins. Think about how can you lay out the board to make servicing easy.

Routing the PCB

The proper placement of traces is something that is learned. The only way to do this is to actually route PCBs. A common and effective technique is to run horizontal traces on one layer and vertical traces on the other layer. (Obviously, this doesn't work for single-layer boards.) This tends to create boards with a lot of vias.

Don't run parallel traces closer than necessary. Segregate analog and digital areas. Put ground traces next to sensitive analog lines to act as shields. Do the same for high-speed clock lines to reduce EMI (ElectroMagnetic Interference) and crosstalk. Pay close attention to parts placement. It's amazing how this can simplify routing.

Do *not* use an auto-router, unless it's really smart (and expensive). The typical, low-cost routers only connect points together. They don't consider the length of the trace, which traces are analog and which are digital, which lines are sensitive, ground loops, etc. As we've seen, subtle points can make a significant difference in how the PCB performs.

It's easier to lay out the board yourself than to chase down elusive errors made by a machine.

PCB Files and Formats

Getting your PCB made commercially requires that you send your design via the Internet (there are a few exceptions). You will need the following files in "Gerber" format for a standard double-sided PCB: 1) top trace layout, 2) bottom trace layout, 3) silkscreen (if used), 4) soldermask (if used), 5) an aperture file, and 6) Excellon drill file. The Gerber format is a standard PCB format that virtually all layout software supports.

We've already discussed items 1 through 4. The Gerber files define the trace placement, but don't specify the physical sizes. The aperture file does this with a short list of "flash codes." Additionally, the Gerber files don't specify the actual size of the holes to be drilled in the PCB. The Excellon drill file tells the manufacturer where the holes are and what size they are supposed to be. Drilling and etching are two separate procedures. When you send these files, be sure to add a short "Read Me" file that relates your file names to the physical parts of the PCB. This saves time and confusion.

Conclusion

It is important to do printed circuit board layout properly. It requires common sense and attention to detail. Hopefully, this overview has provided some insights that will be useful to you. **NV**

Tech Forum

QUESTIONS

I have three radios that use an LM386 for the audio output. This chip tends to be noisy. (It produces audio hiss.) Are there any circuit modifications that can be applied to this chip to make it less noisy?
#7041 **John Morgan**
Smyrna, GA

I have been looking for years for a circuit to sense cars in my driveway. I know that the traffic lights use a single wire loop in the pavement and I assume that it is some kind of tank circuit tied to a PLL. I would appreciate any information on the subject.
#7042 **William Rogers**
via Internet

I work at an electronics repair depot. There are times when we do not have documentation or even a parts list for the equipment that we repair. This isn't too much of a problem until it comes time to identify SMT devices (like the SOT-23 style) that have only a device code — like "R2C." Is there some universal standard for these codes and if so, where can I find them? Sometimes, we can guess what the device is by where it resides in the circuit and search manufacturers' websites until we find that device code, but this is very time consuming.
#7043 **Dean Hutsell**
via Internet

What is the easiest way to allow my computer to operate 120 VAC motors and lights?
#7044 **Richard Wright**
via Internet

I have several ultrasonic units (Branson 303) with many variable outputs, frequency adjustments, coil attachments, etc. Are there any books on applying this unit as a treasure finder to search for coins, jewelry, etc.? I assume it has the power to search that deep, although I expect I would have to build the right kind of search coil.
#7045 **Paul Recupero**
Portsmouth, RI

I am looking for an I/O board that could control the pan and tilt, zoom, focus, and iris controls on a camera. Ideally, I'd like a PCI board that I could plug into a computer that would have relays to control the functions.
#7046 **Ron Ross**
via Internet

Can anyone suggest a good transistor driver or other circuit that could PWM control halogen lamps (up to 12 amps) at 13.8 V? I will be controlling this driver with a pin on a Parallax BS-2.
#7047 **Paul Deffenbaugh**
via Internet

This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

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ANSWER INFO
• Include the question number that appears directly below the question you are responding to.
• Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address if responding by email or we can not send payment.
• Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also, indicate to that effect.
• Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

QUESTION INFO
To be considered
All questions should relate to one or more of the following:
1) Circuit Design
2) Electronic Theory
3) Problem Solving
4) Other Similar Topics

Information/Restrictions
• No questions will be accepted that offer equipment for sale or equipment wanted to buy.
• Selected questions will be printed one time on a space available basis.
• Questions may be subject to editing.

Helpful Hints
• Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
• Write legibly (or type). If we can't read it, we'll throw it away.
• Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

ANSWERS

[3047 — March 2004]
Does anyone have a simple circuit that can be used to count the number of times a bird goes in and out of a birdhouse?

A very easy way to build an event counter is to use any cheap calculator you are willing to dispose of that is in working condition. It must be able to do "constant" calculations, in which a constant number is added to several different numbers. I believe that all cheap calculators can do this.

Remove the cover and attach wires to the "equals" button contacts. Connect the wires to a switch that is placed to record the bird's movements, such as a microswitch on the floor of the birdhouse near the entrance. When everything is ready, set up the calculator in the "constant"

mode to add "1," consecutively. For my calculator, I type "0 + 1 =" and then — every time the switch closes — the calculator will increment by one, up to the display limit of the calculator.

Howard Krausse
Ann Arbor, MI

[3044 — March 2004]

If I isolate the two prongs of a stun gun, can I use it as a zapper to erase the "memory effect" of NiCad batteries?

A zapper isn't used to fix NiCad memory effect. To do that, just be sure to fully charge and fully discharge your NiCads. A zapper is used to fix shorted NiCads. This happens when they sit around for a long time without being used. Internally, they grow crystalline "whiskers" between the positive and negative plates. A high voltage pulse is used to blow out these whisker shorts.

I wouldn't bother trying the stun gun unless you know which terminals are negative and positive. A very simple zapper only requires two parts — a piezo ignitor from a barbeque lighter and a battery holder. Wire the ignitor to the battery holder using short, large diameter pieces of wire. The metal frame of the ignitor is the positive terminal and the wire coming from the crystal is negative.

Give the battery from 5-10 shots; that should clear it and allow it to take a charge. If not, throw it away — it is too far gone. Locally, they sell barbecue lighters for 99 cents, so it cost me less than $2.00 to build a zapper!

Anonymous
via Internet

[30411 — March 2004]

I have a Drake 2 A communications receiver and would like to replace the obsolete vacuum tubes (6BE6, 6BA6, etc.) with solid state devices (FETs, etc.).

#1 This is covered in the April 1977 issue of *QST Magazine*, pages 45-50.

Ken E. Blair
Fredricksburg PA

#2 Although it's theoretically possible, why would you want to do this? Part of the charm of acquiring old tube radios is bringing them back to life by replacing their old, worn out parts with replacements that are as close to the original as possible.

Vacuum tubes are not obsolete in the sense of not being available. There are zillions (well, a lot, anyway) of vacuum tubes still available at reasonable prices.

The 6BA6 and 6BE6 tubes mentioned can be purchased for less than $5.00 each from Antique Electronic Supply in Tempe, AZ (**www.tubesandmore.com**) or elsewhere. Most vacuum tubes still available are new old stock (NOS) from American manufacturers, such as RCA, Zenith, and others. Also,

China and Russia manufacture many of the most common tubes and export them to the US.

Ed Terry
Lakewood, CO

#3 When I was just starting in electronics, my supervisor liked to say, "There is not anything you can do with a tube that can't be done with five transistors." However, simulating a 6BE6 heptode converter would be a challenge. The 300 volt maximum plate voltage rating would require a high voltage transistor, which typically has lower Ft, so the high frequency bands would suffer.

I don't know of any high voltage depletion mode FETs, so biasing would be an issue. If you were to modify the receiver to operate on lower voltage — say 15 volts — the problem is much simpler. The 6BA6 remote cutoff pentode could be directly replaced with a JFET and voltage divider in the gate circuit. That said, tubes are still cheap enough that I would replace them rather than go to the trouble of conversion.

Russell Kincaid
Milford, NH

[3049 — March 2004]

Does anyone have any suggestions as to electronic schematic development software vendors with up-to-date and extensive symbol libraries?

#1 One of the *Nuts & Volts* advertisers — ExpressPCB — is a printed circuit board (PCB) service bureau which delivers quality, low cost printed wiring boards expeditiously. Their service includes free CAD software with both schematic capture and PCB design capabilities.

The component library is relatively extensive and current. After you have entered the schematic and then created the PCB artwork, you send your data to ExpressPCB via the Internet and your finished, double-sided, plated-through hole boards are shipped within a very days. Here is the URL: **www.expresspcb.com/**

Ronald Schafer
Cuyahoga Falls, OH

#2 If you need unusual symbols that are not found in most schematic software, TinyCAD does not have a large variety of symbols in its library, but it is easy to create and store new symbols in it. The help file explains how to create new symbols and I have created several. TinyCAD is also quite easy to use — almost intuitive after a little experience — and produces schematics that are easier to read than other programs. Also, the price is right — it is freeware! It can be downloaded at **http://tinycad.sourceforge.net**

Bill Stiles
Hillsboro, MO

[4041 — April 2004] aka 4001!

Can anyone help me identify where test point 22 is physically located on a Heathkit Model 4110 frequency counter? I am trying to finish the test sequence in the reference manual.

Test point #22 is located at pin 9 on IC323, an SN74LS74 device. IC232 is located on the main circuit board between the blue and green wires of a nine conductor ribbon cable and is the second IC from the right in column 12. Most test points are located in Heathkit's pictorial 4-2 for the model IM-4110 frequency counter.

Uldis Baumanis
St. Paul, MN

[4043 — April 2004]

Does anyone have a circuit for a solid-state phase converter/inverter? I need to convert 24 VDC to three phase AC to drive 240/480 volt motors. I would also like to vary the frequency from 3 to about 100 Hz. I am currently using an electro-mechanical solution involving a DC motor driving an AC alternator, but I need to increase

the efficiency of the power conversion process.

Unless you have a large supply of free power IGBTs (Insulated Gate Bipolar Transistors) or power MOSFETs and have a lot of experience tracking down and eliminating stray capacitances and inductances, a vent hood for venting the magic smoke that you are sure to let out of the power transistors, and a lot of life insurance, building your own inverter is to be avoided at all costs. I suggest buying a Variable Frequency Drive (VFD). At least some of them will work from a DC supply. Here is just the first site I found **http://kbelectronics.com/products.htm**

Good Luck.!

Tom Tillander
Bay Village, OH

[4045 — April 2004]

Many years back, there were ads in the electronics magazines about converting a TV to an oscilloscope. Does anyone remember how this was done?

The best article of that time period was in *Popular Electronics*, September of 1982, page 63. The title was "Turn Your TV Screen Into an Oscilloscope. Low Cost Device Operates Without Modification on Connections to Your Television Receiver."

This unit sensed the television vertical sweep magnetic field with an antenna outside the case of the TV. Each successive TV horizontal line then became another step in the time base, i.e., rotated 90°. The horizontal oscilloscope time base (X) was displayed on the TV as a vertical line starting at the top left and moving to the lower left. The sweep rate was always fixed at the TV vertical refresh rate of 30 Hz.

Oscilloscope amplitude informa-tion (Y) was presented as the displacement to the right of the horizontal trigger line, presently described as the left side of the screen. To allow viewing negative as well as positive signals, the TV horizontal hold control could be adjusted so the TV horizontal sync bar would be displaced to the middle of the screen. This was usually rather unstable and not always a straight vertical line.

The oscilloscope vertical signal information was coupled back into the TV as interference into the TV antenna so that it bled through the tuner. There is no signal trigger, but some synchronization was accomplished by adjusting the vertical hold control.

The circuit is pretty slick: a +6 and -6 power supply, a 741 opamp with input signal range scales, a 555 timer for output, a transistor for sync input, and an antenna to do the input and the output coupling. Unfortunately, it was limited to the lower audio frequencies with a fixed 30 Hz time base and the time base was unstable with only the TV vertical hold control to help position the signal.

Although limited, the author deserves a compliment for innovative thinking. It is a pleasure to see what was attempted with limited resources over 20 years ago. This is all that I can reconstruct. A good online search, the *Popular Electronics* archives, or a scientific library is probably a good place to find the magazine article.

Don Reed
via Internet

[5046 — May 2004]

I have owned a Fluke 8020A multimeter for about 10 years. It is no longer usable, as the display has turned black. I have contacted Fluke and they do not have a replacement display for this meter — their solution is to buy a new one. Does anyone have a solution to my problem?

#1 I had the same problem with a Fluke 8024 15 years ago. The problem is caused by prolonged storage at high temperature — over 130° F. A week in the refrigerator (not the freezing compartment) cured it. It is still in regular use today. I don't know if your display is too far gone to be restored this way, but it worked for me.

Ed Cartwright
Riverside, CA

#2 Buy a used unit for parts/replacement on eBay. The day I checked, there was one for $9.99. I suspect, given the cost of new LCDs, that this is a cheaper route.

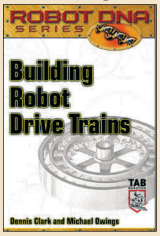
Jon H. Peterson
Rochester, MN

Selected Titles for the Electronics Hobbyist and Technician—

The *Nuts & Volts* Hobbyist Bookstore

Robotics

Building Robot Drive Trains
by Dennis Clark / Michael Owings

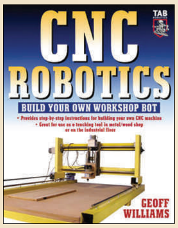


This essential title is just what robotics hobbyists need to build an effective drive train using in expensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems. **$24.95**

Everything you need to build your own robot drive train:

- The Basics of Robot Locomotion
- Motor Types: An Overview
- Using DC Motors
- Using R/C Servo Motors
- Using Stepper Motors
- Motor Mounting
- Motor Control
- Electronics Interfacing
- Wheels and Treads
- Locomotion for Multipods
- Glossary of Terms, Tables, and Formulas

CNC Robotics
by Geoff Williams



Written by an accomplished workshop bot designer/builder, *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly because you designed it. **$34.95**

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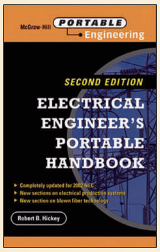
Robot Mechanisms and Mechanical Devices Illustrated
by Paul Sandin

Both hobbyists and professionals will treasure this unique and distinctive sourcebook — the most thorough and thoroughly explained compendium of robot mechanisms and devices ever assembled. Written and illustrated specifically for people fascinated with mobile robots, *Robot Mechanisms and Mechanical Devices Illustrated* offers a one-stop source for everything needed for the mechanical design of state-of-the-art mobile bots. Written by a leading designer of robots used at the horizon of mobile robotics, this resource offers a collection of both new and classic robotic mechanisms and devices unmatched in scope — from such high-level sources as the mechanical engineers' mainstay, *Mechanisms and Mechanical Devices Illustrated*. Paul Sandin's superlative reference also brings you new robotic mechanisms and devices that have never before been collected! **$39.95**

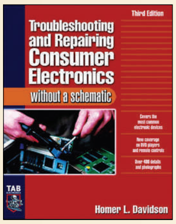
Electrical Engineer's Portable Handbook
by Robert Hickey



This quick look-up, working tool — packed with tables, charts, and checklists — takes the guess work out of almost any electrical design task or calculation. Indispensable for electrical engineers, designers, and technicians, the *Handbook* provides immediate fingertip access to the fundamental information busy professionals need for everyday use in the field. **$59.95**

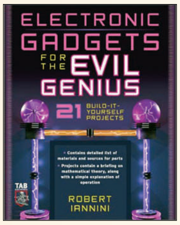
Electronics

Troubleshooting & Repairing Consumer Electronics Without a Schematic
by Homer Davidson



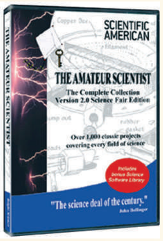
In this book, Homer Davidson gives you hands-on, illustrated guidance on how to troubleshoot and repair a wide range of electronic products — when you can't get your hands on the schematic diagrams. He shows you how to diagnose and solve circuit and mechanical problems in car stereos, cassette players, CD players, VCRs, TVs and TV/VCR combos, DVD players, power supplies, remote controls, and more. **$34.95**

Electronic Gadgets for the Evil Genius
by Robert Iannini



The do-it-yourself hobbyist market — particularly in the area of electronics — is hotter than ever. This books gives the "evil genius" loads of projects to delve into — from an ultrasonic microphone to a body heat detector, all the way to a *Star Wars* Light Saber. This book makes creating these devices fun, inexpensive, and easy. **$24.95**

The Amateur Scientist 2.0 Science Fair Edition
from "The Amateur Scientist" column



This CD contains the complete collection — 73 years — of articles from *Scientific American Magazine*'s legendary column "The Amateur Scientist," plus a second Science Software Library CD with dozens of shareware and free-ware programs to feed the passion of any science nut. With over 1,100 projects to challenge science enthusiasts of all ages and skill levels — rated by cost, potential hazard, and difficulty — this is the ultimate resource for anyone interested in home-based science. If that's not enough, it also contains over 1,000 bonus pages of additional how-to science techniques that never appeared in *Scientific American*. Great for science fair students, hobbyists of all ages, and home-schoolers! In fact, *The Amateur Scientist 2.0* contains a special primer for science fair students. Fully text-searchable and packaged in an attractive double-CD case, this remarkable browser-based product runs seamlessly on every platform — Windows, Macintosh, Linux, and Unix.

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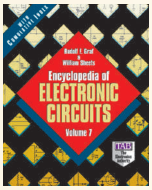
Encyclopedia of Electronic Circuits, Volume Seven
by Rudy Graf



Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits*, Volume Seven, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. This collection includes the latest designs from industry giants, such as Advanced Micro Devices, Motorola, Teledyne, GE, and others, as well as your favorite publications, including *Nuts & Volts*! **$39.95**

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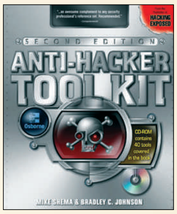

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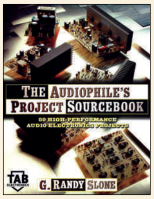
The Audiophile's Project Sourcebook: 80 High-Performance Audio Electronics Projects
by G. Randy Slone



The Audiophile's Project Sourcebook is devoid of the hype, superstition, myths, and expensive fanaticism often associated with high-end audio systems. It provides straightforward help in building and understanding top quality audio electronic projects that are based on solid science and produce fantastic sound! **$29.95**

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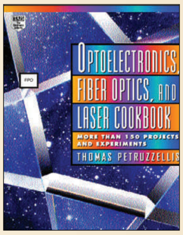
Build Your Own Printed Circuit Board
by Al Williams

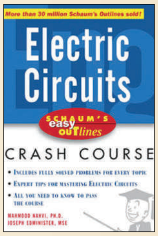
With *Build Your Own Printed Circuit Board*, you can eliminate or reduce your company's reliance on outsourcing to board houses and cut costs significantly. Perfect for advanced electronics hobbyists as well, this easy-to-follow guide is by far the most up-to-date source on making PCBs. Complete in itself, the handbook even gives you PCB CAD software — on CD — ready to run on either Windows or Linux. (Some PCB software costs from $10,000.00 to $15,000.00!) **$27.95**

Optoelectronics, Fiber Optics, and Laser Cookbook
by Thomas Petruzzellis



This is a practical guide to one of the hottest fields in electronics and optical circuits. A collection of hands-on experiments and projects for the student, technician, and hobbyist, it explains optoelectronics in nontechnical terms. Projects show how optical circuits work and how to use them in practical and efficient ways. You'll save time, money, and energy with dozens of do-it-yourself projects — from laser alarm systems to high-speed fiberoptic data links. Circuit diagrams, schematics, and complete parts lists accompany each project and an appendix lists suppliers for needed parts. **$29.95**

Schaum's Easy Outline of Electric Circuits
by Mahmood Nahvi / Joseph Edminister



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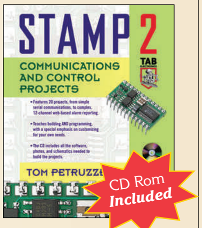
Microcontrollers

STAMP 2: Communications and Control Projects
by Thomas Petruzzellis



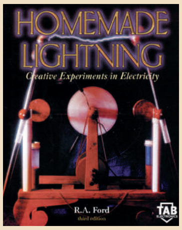
With the help of detailed schematics, informative photos, and an insightful CD-ROM, *STAMP 2: Communications and Control Projects* leads you step-by-step through 24 communications-specific projects. As a result, you'll gain a firm understanding of Stamp 2 and its programming methodologies — as well as the ability to customize it for your own needs and operating system. **$29.95**

Programming and Customizing the OOPic Microcontroller
by Dennis Clark

If you're a robotics professional or hobbyist, here's the one book you'll need to keep your work on the leading edge — *Programming and Customizing the OOPic Microcontroller*. This is the official OOPic handbook, fully endorsed by Savage Innovations — the world's only manufacturer of OOPic microcontrollers. As the first book of its kind, this volume is destined to become the standard against which all other OOPic books will be judged. **$39.95**

High Voltage

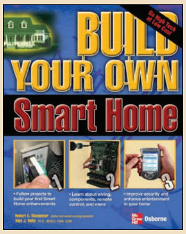
Homemade Lightning: Creative Experiments in Electricity
by R. A. Ford



Enter the wide-open frontier of high-voltage electrostatics with this fascinating, experiment-filled guide. You'll discover how to make your own equipment, how electricity is used in healing, and how experiments in high potential physics work! **$24.95**

Home Entertainment

Build Your Own Smart Home
by Anthony Velte

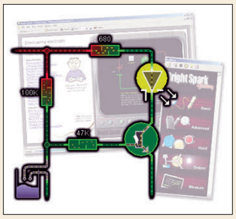


Wow! If you've got the time and inclination, there isn't anything that cannot be automated in your home. This one stop resource uses clear, step-by-step instructions and illustrations to show you how to plan and install smart home systems. Discover projects for automating entertainment systems, home security systems, utilities, and more. **$29.99**

If you don't see what you need here, check out our online store at **www.nutsvolts.com** for a complete listing of the titles available.

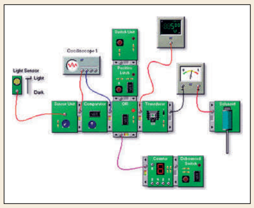
THE $49.95 SOFTWARE SOLUTION FOR STUDENTS, HOBBYISTS, AND "MIDNIGHT" ENGINEERS

Pulsar has released a line of software to aid in electronic design and construction that is priced within the reach of the hobbyist.



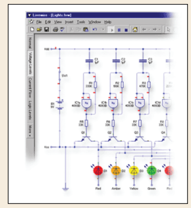
Bright Spark teaches interactive basic electronics with complete animation. If, for example, a circuit was driven with too much current, components will "burn up" on screen. It makes learning electronics fun.

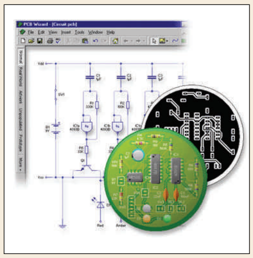
Control Studio uses interconnecting "modular blocks" (mini-functional circuits) that are plugged together to form a complete circuit with full simulation and — if Livewire is concurrently running — it will draw out



the entire schematic in one shot.

Livewire is a schematic design and simulation package powered by a highly accurate physics simulation engine. Grab the components you need, connect them together, then press "play" for simulation.





PCB Wizard is an innovative package for designing single- and double-sided printed circuit boards. It includes many exciting features, such as "copper pour," which fills all voids to reduce copper to be etched.

For more information, contact:

PULSAR
1947 Sandalwood Pl.
Clearwater, FL 33760
727-524-1500 Fax: **727-524-1225**
Email: **mail@pulsar.gs**
Web: **www.pulsar.gs**

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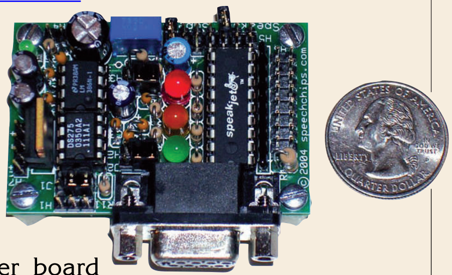
SPEAKJET SUPERCARRIER



Www.speechchips.com has announced the addition of a new, exclusive product — the SpeakJet SuperCarrier — to its line of speech synthesizer products.

The SuperCarrier is a full-featured carrier board for the Magnevation SpeakJet single chip speech synthesizer.

The SpeakJet generates 72 speech allophones, 43 sound effects, and 12 DTMF Touch Tones.

Through the selection of these sounds and by controlling the pitch, rate, bend, and volume parameters, users have the ability to produce unlimited phrases and sound effects. The SuperCarrier can be connected directly to a PC or it can be embedded in a stand-alone project, such as a talking robot. It allows full access to all the SpeakJet features.

The SuperCarrier is available as a double-sided PCB or in kit form.

For more information, contact:

WWW.SPEECHCHIPS.COM
35 Middle St.
Westbrook, ME 04092
Fax: **928-569-4997**
Email: **ken@speechchips.com**
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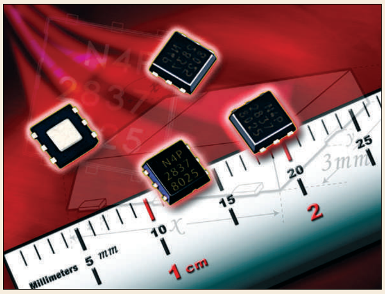
INDUSTRY'S HIGHEST OUTPUT CURRENT FOR CMOS LDO VOLTAGE REGULATOR



Seiko Instruments' S-1170 Series LDO (load drop out) voltage regulator is the highest output current (800 mA) capable CMOS based LDO. The CMOS process permits ultra-low current consumption of 80 µA during operation and 0.1 µA during shutdown, assuring energy-efficient operation.

An ON/OFF circuit further ensures battery longevity for increased energy management. Optimized for noise sensitive applications, this device has a 70 dB ripple rejection ratio that is achieved without the need of an external bypass capacitor.

The SOT-89-5 and six-pin HSON(A) compact package designs provide for high density mounting, while superior noise and low quiescent current specifications make the S-1170 the perfect power supply option for a wide array of electronic equipment including PDAs, notebook PCs, hand-held games, home security equipment, digital cameras, and portable audio devices.

Other key specifications that add to the high performance and reliability of this design include an output voltage range of 1.5 V to 5.0 V in 0.1 V increments and an LDO voltage of 120 mV, typical. A built-in thermal shutdown circuit prevents potential damage caused by heat, while a built-in overcurrent protector prevents the load current from exceeding the current capacitance of the output resistor.

For more information, contact:

SEIKO INSTRUMENTS USA, INC.
2990 Lomita Blvd.
Torrance, CA 90505
Tel: **310-517-7884**
Email: **jim.schlumpberger@siu-la.com**
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MULTIMETER WITH BUILT-IN INFRARED LASER THERMOMETER

Tritronics, Inc., is now offering the Extech EX470, which has all the features of a deluxe DMM, such as a 4,000-count backlit display, true RMS, relative function, duty cycle, resistance, capacitance, and frequency measurements, auto power off and Data Hold. Basic accuracy is ±0.3%. DC/AC voltage is 0.1 mV to 600 volts, current 0.1 microamp to 20 amp.

The meter's rubber holster with lead storage includes CAT III test leads, a multi-position tilt stand, Velcro hanging strap, bead wire temperature probe, and 9 volt battery. All switch positions are color-coded, as are the input jacks, which provide warnings if probes are inserted incorrectly. The continuity beeper is loud enough for use in noisy areas. It is CE and UL listed. The non-contact infrared thermometer adds to the versatility of this precision instrument. It can be used as a laser pointer or as a device for measuring heat in Celsius or Fahrenheit by taking non-contact surface temperature measurements. The infrared features 8:1 distance to target ratio with 0.95 fixed emissivity.

The many uses include HVAC applications, checking for hot lighting ballasts, overheated motors, or problem parts in unsafe or inaccessible circuits.

Tritronics' website provides details of this and other test and measurement items, in addition to a full array of electronics tools and equipment.

For more information, contact:

TRITRONICS, INC.
1306 Continental Dr.
Abingdon, MD 21009
Tel: **800-638-3328**
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Circle #113 on the Reader Service Card.

by Fernando Garcia

Self-Powered Digital Voltmeter

Build a Nice Add-On for Your Car or Truck and Learn a New Opamp Trick

This Month's Projects

Digital Voltmeter 52
Enigma Machine 56
Measure Capacitance . 61

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

The simple circuit described in this article allows your digital meter to be self-powered from the same voltage it measures. This sounds simple and straightforward, right? Unfortunately, it is not.

The issue is that digital meters — with all of their advantages over analog meters — require a separate voltage source from the one they are intended to measure. This means that you need either batteries — which require replacement — or an isolated power supply — which means added bulk, expense, and wiring.

Wouldn't it be nice to have a drop-in replacement for an analog meter?

The idea for this arose from the time when a friend asked me if I could help him add a digital meter to his gadget-laden truck. He was concerned about the truck's battery condition during his many outdoor trips. He did not want to be left stranded in a remote wilderness with a dead battery and I could certainly empathize with his concern.

I told him that I would think it over and, on my drive home, realized that my own vehicle did not have a battery meter, either. It turns out that — in these days when a single vehicle has more electronic devices than an entire household did a generation ago — many automobile manufacturers have decided to remove them and include only panel lights. Thus, I had the idea for this project.

I also realized that, for the project to be successful as a drop-in replacement for an analog meter, it would need to have a two wire connection and minimal supply current requirements to allow it to be easily connected and left on permanently without undue battery drain.

My target then, was to have a complete

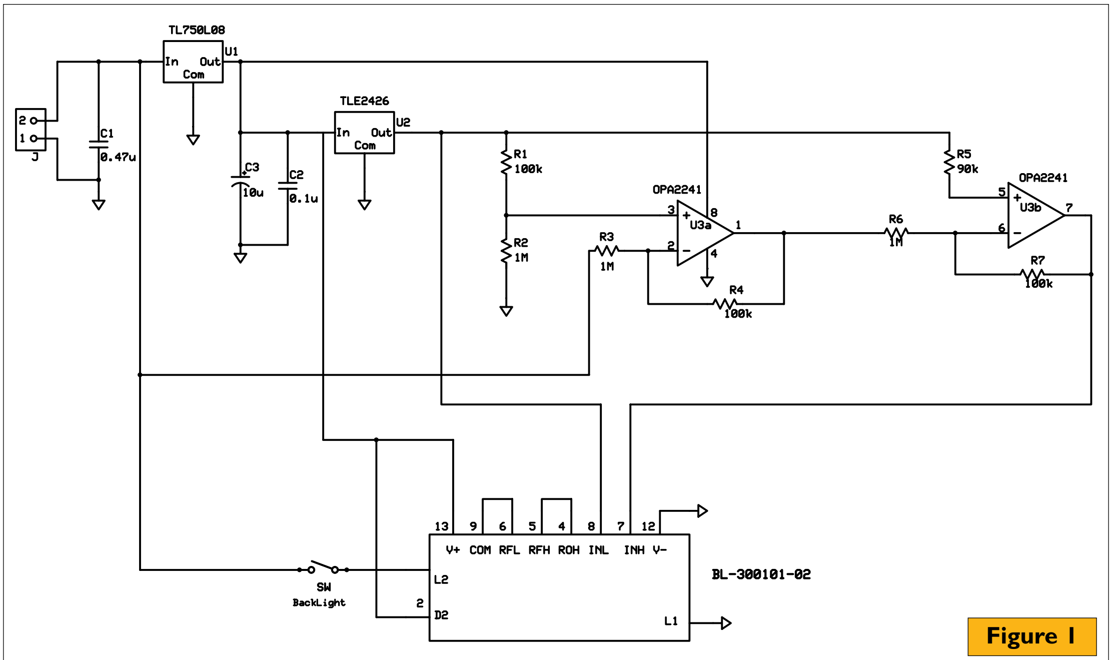


Figure 1

circuit that would draw an input current of less than 1 milliamp.

Common Mode Range

One of the advantages of a digital meter over an analog one is that its input can measure positive and negative voltages without reversing the input leads. To do so, the meter must have a bipolar power supply. Since a dual supply is not a feasible approach in battery-powered equipment, the solution that engineers decided on is to have the return (negative) input referenced to a mid-supply level. Since the supply for battery-powered meters is floating and independent of any external reference, it is of no concern that the meter's negative sense input is not tied to the battery negative.

The positive input resistor voltage dividers are also referenced to this mid-supply, which usually converts the measured voltage to the ±200 millivolt measurement range. Additionally, as long as the return input is referenced to this mid-voltage within its common mode range — usually plus or minus 1 volt — the meter will be able to function.

In a 9 volt powered meter, the battery's negative lead sits 4.5 volts below this mid-supply reference — way too far from its common mode range for the meter to function properly if the negative input was tied to it. Some meters (especially those functioning with 3 to 6 volt batteries), use a charge pump to artificially generate a negative supply voltage. Although this is a practical solution, those circuits consume currents in excess of that of the meter. Since a very low current consumption was one of the goals, this option was ruled out.

Opamps to the Rescue

It is a sure bet that almost everyone who is interested in electronic circuits has experimented with operational amplifiers. It is common knowledge that these devices are easily used as voltage amplifiers, but it is not very well known that they may also work as voltage level shifters. Thus, a voltage which is referenced to the negative supply lead may be applied to the meter's floating input. The trick is explained in the sidebar.

Having a digital voltmeter that doesn't draw power away from your vehicle is a very simple and straightforward project, as seen in the schematic in Figure 1.

The complete circuit is fed from a low dropout voltage regulator, U1, which maintains the regulated 8 volts. The current consumption is so low that no heatsink is required. The tantalum capacitor, C3, is required for stability.

Although the meter — having been designed for portable operation — is rated for 9 volt nominal

Teaching an Old Dog a New Trick

If you are reading this, it is likely that you are very familiar with the classic opamp gain formulas:

Inverting gain Av(-) = -Rf/Ri
Non-inverting gain Av(+) = 1 + Rf/Ri

What this essentially means is that, if you have easy round numbers — a 100K feedback resistor and a 20K input resistor — you will obtain a gain of -5 if your signal is fed to the inverting input and a gain of +6 if the signal is fed to the non-inverting input. It does not get any simpler than that.

Of course, for this to be true, it is assumed that the signal input is grounded for the output to be also referenced to ground. Of course, for this to be true, it is assumed that a 0 output voltage implies a 0 input voltage — since they share the same ground reference.

What if you would like to have a nonzero output voltage for a zero input voltage? What if you want it to be 4 volts to accommodate the digital meter's common mode range? Then you must also level shift the signal. You can simultaneously level shift and add gain to an input signal.

In our particular case, we need to convert from a range of roughly 9 to 15 volts to 90 to 150 millivolts to accommodate the meter's 200 mV range. This means a gain of -1/100. (Yes, you can have gains lower than 1.0.) If we select a 1 MΩ input impedance, then the first equation will show that the feedback resistor must be 10 KΩ.

Following the second equation, the non-inverting gain with those resistor values is now 1 + 1/100 or 1.01. The compensating voltage (shown as a battery in Figure A) will be connected to that terminal and will see that gain value.

What should the compensating voltage be? Simple: the desired output voltage (ex., 4 volts) divided by that gain or 4/1.01 = 3.9604.

Where am I going to get such an odd voltage? Again, this is simple; I'll use a resistive voltage divider from the 4 volt reference with the same gain-setting resistor values as the opamp. The end result is shown in Figure A.

The only problem with such a circuit is that the output is inverted; an increasing input voltage will result in a decreasing output voltage. To make it the proper polarity, an additional inverting section must follow it. To keep all resistors equal then, it is wise to split the gain in the two sections — in other words, -1/10 and -1/10. As the signal fed to the second opamp is already level-shifted, its non-inverting input is simply returned to the reference voltage.

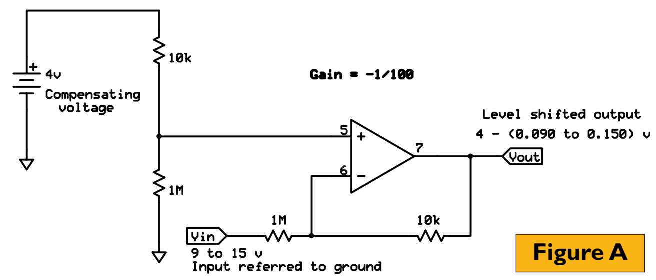


Figure A

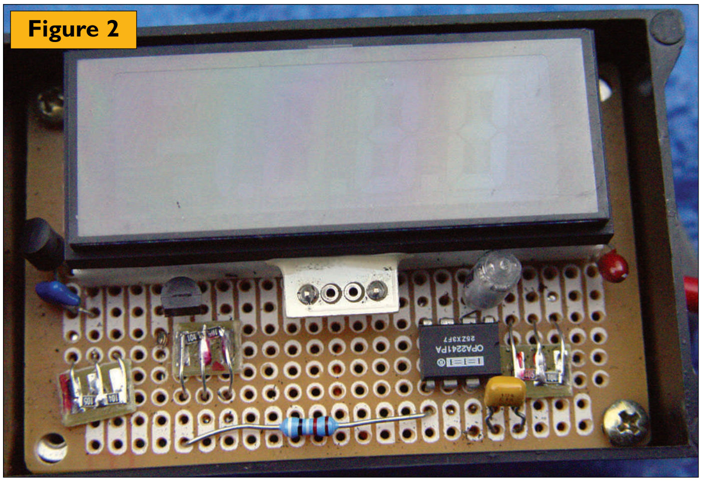


Figure 2

Parts List

R1, R3, R6	1 MΩ, 0.1% (see text)
R2, R4, R7	100 KΩ, 0.1% (see text)
R5	91 KΩ, 5%
C1	0.47 µF, 50 volt ceramic
C2	0.1 µF, 50 volt ceramic
C3	10 µf, 16 volt tantalum
U1	TL750L08 8 volt low dropout regulator
U2	TLE2426 precision ground reference
U3	OPA2241 dual opamp (preferred), LC272A (alternate)
Sw	NO switch
Disp	9 volt supply, 200 mv DC input, green LCD panel meter (Modutec BL-300101-02, etc.)
J1	Fused cigarette plug

operation, it remains fully functional all the way down to 7.2 volts. Choosing an 8 volt, low dropout regulator is required for proper operation with a fully discharged battery.

A dual opamp, U3, plus its associated resistors, performs both the voltage level shifting and the precision voltage division, converting the 8.5 to 15 volt input to a range of 85 to 150 millivolts centered around mid-supply voltage or 4 volts. The processed voltage is then fed to the digital meter.

Of course, these 4 volts could simply be generated with a same value resistor divider, but, to prevent external loading from affecting the accuracy, those values would have to be very low and the current consumption would exceed that of the rest of the circuit many times over. A buffer could be used, but the best solution by far is a virtual ground generator IC from Texas Instruments (U2). This device splits the supply voltage accurately in half, simultaneously maintaining low noise and quiescent current.

Building the Project

I decided to build this project since I could get my hands on some digital panel voltmeters (200 mV DC range) at a very reasonable price. Brand new meters retail in the $40.00 to $70.00 range, which is somewhat pricey, but you can procure them in the surplus market for much less, usually with only minor cosmetic defects. (The defect on mine was that the decimal point would not light up.)

Alternately, you could use a cheap, 9 volt powered multimeter set to the 200 millivolt DC range. If you are adventurous enough, you could build a meter from scratch employing a suitable IC, like the ICL7126 from Intersil

(**www.intersil.com/data/fn/fn3084.pdf**). The choice is yours.

Other than that, the project uses point-to-point wiring techniques and can be built on a perf board inside a small plastic box, as shown in Figure 2. Observe proper ESD handling techniques when you work with the devices.

The only thing to keep in mind to ensure optimum accuracy is careful selection of the opamp device and the resistors. Remember, the meter's last digit is measuring tenths of a millivolt. The opamp must be a precision, very low offset, very low supply current device. Part OPA2241 from Texas Instruments meets those requirements and won't cost you an arm and a leg.

However, if you want to go easier on your budget, I've listed a more economic opamp in the Parts List.

For the resistors, 0.1% devices are required. Again, if you are cost-conscious, readily available 1% resistors may be used. The trick here is to use a multimeter to select the ratios between R1 and R2, R3 and R4, and R6 and R7. Resistors are usually sold in 10 piece packs, which makes a good sample size from which to cherry-pick the devices. For instance, Table 1 shows the values from an actual sample of standard 1% resistors and the colored highlights indicate suitable matching for the resistor pairs outlined above. Values in both columns are in KΩ.

R1, R4, R7	R2, R3, R6
100.3	990
99.7	1,008
99.7	992
99.6	1,000
100.4	1,002
100.9	1,006
100.0	1,004
99.1	998
100.4	1,008
99.9	1,009

Table 1

Figure 3

In my particular case, the digital meter had an optional 12 volt backlight. Since the light may actually consume hundreds of times more current than the complete circuit, it is wise to include an on/off switch to turn it on only when required by lighting conditions. If the meter you get has a 5 volt backlight — another popular option — you will have to add a small, 5 volt regulator to power it from the automobile battery.

The project was assembled on a small plastic box and fitted with a cigarette plug connector. It can then be attached to any suitable surface using Velcro (see Figure 3). Although cigarette receptacles in vehicles are always fused, the listed plug has an internal fuse. Since its rating is smaller, any malfunction will cause it to blow up without knocking out your lighter's main fuse. **NV**

Mr. E. MacHine: The Enigma Machine — Part 2

Lightning in the Palm of Your Hand — Safely!

Last month, we examined two designs for building the Enigma Machine. We saw that it is a device that produces pulses of 1200 volts at a rate of a few Hertz to a couple of hundred Hertz. Because the high voltage is completely isolated from the outside, no significant current flows. Therefore, it's safe to play with. This month, we'll look closely at the vibration effect, as well as experiment with other properties of high voltage.

The Specifications Table provided is for the microprocessor (µC) version. There are a few differences from the 555 timer version. The input voltage for the 555 version must be 12 volts DC with the proper polarity. Obviously, the physical characteristics will be different if you used a different case. The output pulse voltage is different. The µC version outputs a decreasing voltage as the frequency increases.

The 555 timer version outputs the same voltage at any frequency. I did this because, at higher frequencies, the rapid pulses seemed to be on the edge of annoyance for some people. If you want to maintain high pulse voltages regardless of frequency setting, change R2 from 1M Ω to 100K Ω. (This is the resistor that connects the base of the transistor to ground in the µC version.) All of the experiments described below use this modification.

Notes

A substantial amount of research into these effects has been done. The explanations provided here are based on that research. However, it is clear that some effects are subtle and the exact mechanisms are not precisely known. This means that your own experiments may turn up something new.

There are a number of factors that can cause variations in some of the experiments (room humidity seems to be one of them). The experiments provided are usually reliable (unless otherwise noted). Be sure to record any experiments you do to try to determine what these factors are. It should also be noted that some of these effects are not well known. In fact, I have not been able to find any reference to the vibration effect.

Vibration Effect Experiment

Place an empty soda can on the machine and turn it on to a high rate (see Figure 1). Now, gently brush a dry finger across the side of the can. (You may need to hold the can in place with something that's well insulated — like a screwdriver handle.) You will feel a vibration at the frequency setting of the machine, but this only happens

Figure 1. Rubbing the can with a dry finger causes a vibration at the frequency setting of the machine. You may have to hold the can steady with an insulator, like a screwdriver handle. (Don't touch the can with your hand.) The plate is optional.

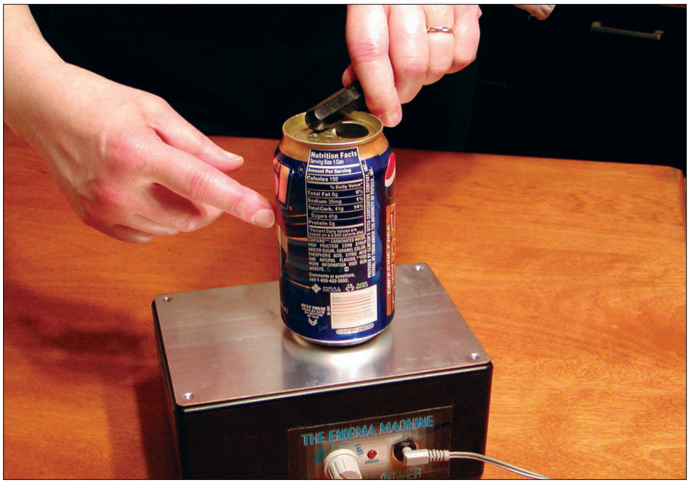


Figure 2. The vibration effect can pass right through a person without any sensation, but the effect is reduced.

when your finger is dry and moving. A stationary finger or a damp finger produce no effect. Why?

Now, hold the can in your hand and place your other hand on the top of the machine (Figure 2). Have someone else brush the can with a dry finger. Surprise! The vibration effect passes right through you and the can to the other person (although reduced by roughly half). You don't feel a thing. See how many people you can pass the "vibration" through. It is possible to eliminate the can and lightly brush the back of the other person's hand. The effect is quite reduced, but still present.

Turn the can upside down, place it on the machine and brush the bare aluminum bottom with your finger. The vibration effect is greatly reduced or eliminated. Why? (If the can is painted on the bottom, place the aluminum plate on the machine, as shown in Figure 3, and brush that.)

Figure 3. For some experiments, a metal plate on the machine increases the strength of the effects.

Vibration Explanation

The vibration effect was first discovered by accident when I brushed my ear against a strong electromagnet that was being energized with a powerful, high frequency signal (about 12,000 Hz). A sound was heard when the ear was brushed, but not when it was stationary. Why? Was it vibration or some type of nerve stimulation? Simple experiments showed that it was mechanical vibration.

There are two questions about this effect. The first is why a finger must be brushed to feel the vibration. (A stationary finger does not create the effect.) The second question is why the finger must be dry. (A damp finger

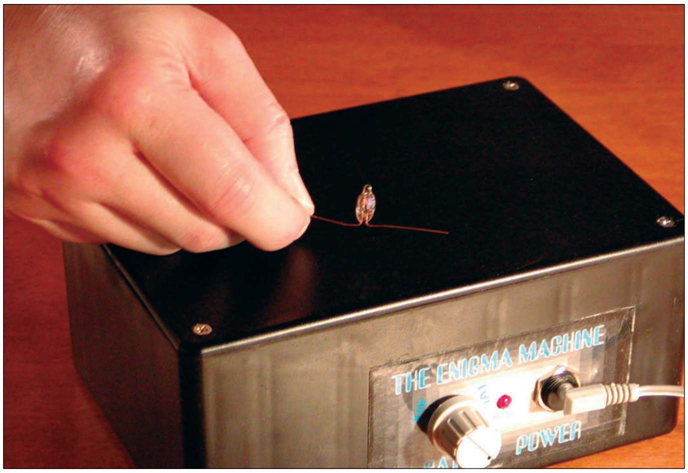


Figure 4. A small neon lamp glows by itself when held close to the machine.

does not create the effect, either.)

The finger-brushing effect appears to be due to a combination of factors that are both electrical and chemical. It is known that a high voltage electrical charge will cause polar molecules to orient themselves according to the electrical field impressed on them. (Polar molecules have a non-uniform electrical distribution. One part is positive and the other part is negative.) Water is a highly polar chemical.

Additionally, most complex organic molecules are polar. The result is that there is an electrical attraction during the pulse because of the molecular orientation. (A negative pulse causes the positive parts of the molecules to orient towards the plate. These positive/negative charges attract each other.) When the pulse is over, there is no attraction.

This results in a variable friction when the finger is moved. The friction is higher when the pulse is on and lower when the pulse is off. The variation in friction is not noticed if the finger is stationary. A close analogy is rubbing a nail over a file. The ridges in the file cause a variable friction. Rubbing the nail over the file causes a vibration to be felt. A stationary nail does not vibrate.

Charge Conduction

It has been noted that there is person-to-person conduction of the vibration effect (and other effects). There is no sensation at all when this occurs. (In fact, 1/4" sparks can be drawn into or out of a person without sensation. This requires a much more powerful apparatus and special conditions.) It appears that this conduction occurs because of the molecular rotation of polar molecules (as noted above).

This is very different from an ordinary electrical current because there is no free movement of electrons. The polarization of molecules causes a charge shift that is propagated like a bucket-brigade. Since there is no free electron movement, there is no measurable electrical current.

Consider this analogy. Suspend a number of bar magnets with threads so that they can easily rotate. Keep them far enough away from each other that they do not pull together, but keep them close enough that their magnetic fields overlap. If this is done properly, they will orient themselves into a straight line. This simply shows the magnetic attractive force.

Now, manually rotate any magnet 180°. All of the other magnets rotate, as well. By forcing a local change in the magnetic field, a magnetic effect is propagated

Specifications

Input power requirements:
Operating Voltage: 8.5 to 18.5 volts DC or AC
with automatic shutdown outside of range
Maximum input voltage: 30 volts
Operating Current: 15 mA maximum (@ 14 VDC)
Input power connector: 2.1 mm standard male power jack
Input power polarity: Any (automatic polarity control)

Output pulse characteristics:
Pulse repetition range: 7.8 Hz to 256 Hz
Typical pulse voltage: 1,200 volts (peak to peak) maximum
down 10% at 50 Hz
down 50% at 140 Hz
down 75% at 256 Hz (see text)

Capacitive coupling: 200 pF (with supplied plate)
Pulse shape: Damped sine wave (down 63% per cycle)
Sine wave frequency: 3,030 Hz (typical)
Pulse Current: Indeterminate (Note 1)

Transformer driver characteristics
Transformer type: 12 volt automobile ignition coil
Primary current: 400 mA (@ 14 VDC)
Input pulse duration: 100 mS
Input pulse duty cycle: 0.07% @ 7.8Hz, 2.5% @ 256 Hz (Note 2)

Physical characteristics:
Length: 7.050" or 180 mm
Width: 5.875" or 150 mm (including knob)
Height: 3.175" or 80 mm
Weight: 32.0 oz or 0.850 kg

Note 1. The current is not determined because different measures provide different values. The maximum current measured has been about 3 mA. However, some tests show no detectable current.
Note 2. The output voltage drops as the frequency increases.

through all of the magnets. It's important to realize that (in theory) the propagation distance can be arbitrarily long. It simply depends on how many magnets you line up.

This explains why there is no feeling when the effect passes through you. Your molecules are rotating, as opposed to an electric current passing. Please take this molecular explanation at face value for now. I'll provide ample evidence for this mechanism in a subsequent article.

Why does the finger have to be dry? The reason appears to be a skin effect, which is described below.

Skin Effect

Note: There is a different "skin effect" that has to do with the distribution of an electric current through wires at high frequencies. At high frequencies, the electric current stays near the surface of the wire. Hence, the name "skin effect." That effect is not at all related to the following.

It was quickly noted that a damp finger does not show the vibration effect. However, if the finger was insulated from the bare metal plate, the effect returned. A close examination of the vibration effect explains why.

In order for the electrical attraction to occur, there must be a positive and negative charge difference. Obviously, there can be no charge difference if there is an electrical connection. If there is no charge difference, there is no charge attraction. This is the reason that the finger must be dry or that a thin electrical insulator is needed. This insulator can be a thin piece of plastic wrap or a thin layer of paint. Clearly, the thinner the insulator, the greater the effect, because the charges can be brought closer together.

More Vibration Experiments

You can devise your own experiments to test this. Put the metal plate on the box and hold thin plastic wrap tightly around your finger. (The plastic wrap on the metal plate sticks too much.) Try different things — like an apple or a banana or a piece of anodized aluminum.

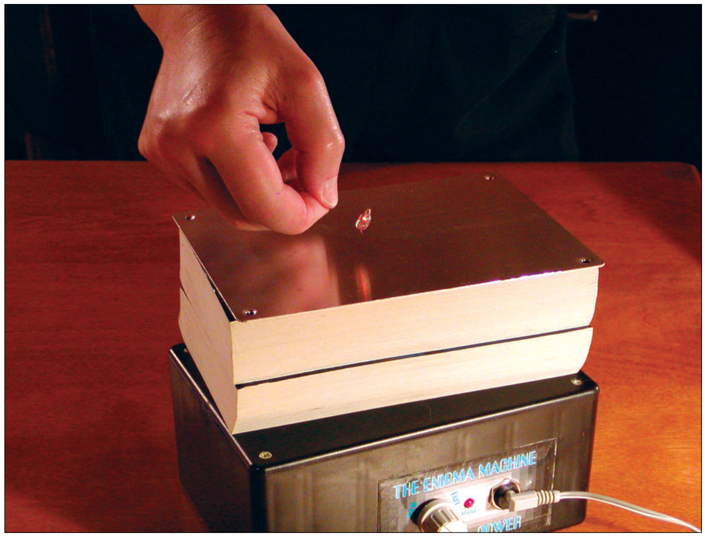


Figure 5. The neon lamp glows much more brightly and at a farther distance from the machine if the plate is used. (The spacers are two paperback books.)

Enigma Safety Notice

Please Use Common Sense ...

1. This article deals with high voltage and high voltage effects. When built and used as described, it is felt to be completely safe. Improper use and construction can cause electrical shock.

2. Several experiments demonstrate effects that pass through the body of the user. Therefore, it is not recommended that anyone with a pacemaker or other embedded electrical device participate in these experiments, nor should it be used in very close proximity to any electrical equipment where electromagnetic interference could cause safety concerns.

3. Several experiments have shown subtle biological effects on plants after continuous exposure of days to weeks.

(Don't use fruit right out of the refrigerator because moisture will condense on it.)

What happens when you put a sheet of paper over the plate and rub that? If you put a thin book on the machine and put the can on top of that (raising the can about an inch from the surface) is the effect still there?

Radiated Power

Take an ordinary, small neon lamp and spread the leads outward. Hold it by one lead over the Enigma Machine and you can see it light up (see Figure 4). This is easiest to see in subdued lighting. How far away from the box can you move the lamp and still see it glow? (Note that different lamps perform differently.)

Put the plate on the box and touch the free lead to the plate. The lamp glows brightly. Now, move the plate away from the box and touch the free lead to the plate (see Figure 5). You can move it much farther away before the lamp goes out. Shades of Tesla!

The plate is acting as an antenna. It picks up the electric field and passes it through the plate and lamp into you. Obviously, the metal plate works better than just the lamp lead because it's so much bigger and collects more energy. Try different orientations of the plate. Try different antennas. Do rabbit ears work? How about a bowl of water? Be creative.

Somewhat surprisingly, the Enigma Machine is very well-behaved when it comes to ElectroMagnetic Interference (EMI). You would normally expect that such "radiated power" effects would cause significant problems with radios and TVs. There is very little EMI generated.

Teasers for the Next Installment

If you run the Enigma Machine on batteries, the effects are greatly reduced or even eliminated. If you use the AC adapter or any power supply connected to the AC line, the effects are much greater. If you use batteries and touch just an oscilloscope probe tip (without grounding the probe) to either battery terminal, the effects return (use a 1X probe). The oscilloscope doesn't have to be on, but it does have to be plugged in. Can you figure out what's going on?

Try to measure the current of the pulse. Use different methods. Are the results the same?

We'll go over these points in detail next time and add more experiments to try. Later, we'll look at how this related to "Kirlian Auras" and provide a physical explanation for what's happening. We'll also see how to identify chemical solutions without actually touching them. Stay tuned. NV

The Capacitance Connection

Use a Common Tool in a New Way

Several weeks ago, I was installing some low voltage yard lights. After placing the wires where I wanted them, I applied power and one of the strings did not work. I went through the normal troubleshooting of measuring the voltages and resistance. It became quite easy to tell that I had an open somewhere between the transformer and the first light in the string, but where?

I remembered using a multimeter with capacitance capability just days earlier to solve a problem on our manufacturing line. I had used it to detect the capacitance difference between a 16 gauge power cord and an 18 gauge power cord. It only took seconds to recall that the capacitance of the wire is directly proportional to the length, among other things. I had a roll of the yard light wire from the store that had not been opened. It listed 50 feet on the label. I put my multimeter in the capacitance mode, zeroed out the leads, and clipped them on to one end of the wire. The multimeter read 1.05 nanofarads. I calculated the capacitance to be 21 picofarads per foot. I then measured the open wire I had disconnected from the transformer. It measured 158 picofarads. That calculated to be seven feet, six inches. With the use of a tape measure, I found a cut in the wire at seven feet and six inches!

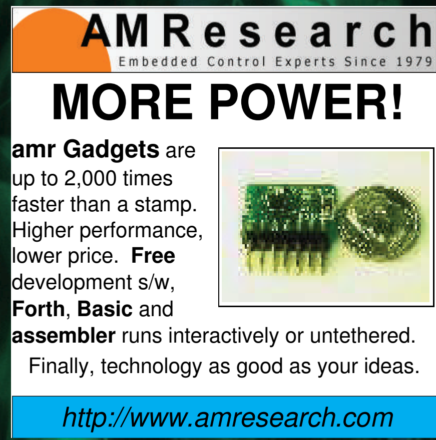
This sparked my curiosity. I took a trip to the hardware store and measured a new role of Romex. A 250 foot roll of 14-2 yielded 5.26 nanofarads — 21 picofarads per foot. The hardware store worker marveled when I told him what I was doing and was amazed when I measured a partial roll and calculated that he had 91 feet left in the roll!

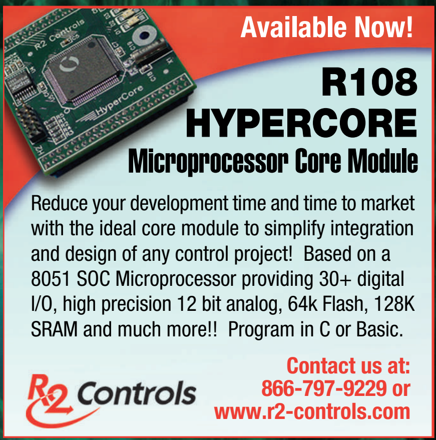
I wondered how good this was. I made some other measurements and calculated the resolution. The capacitance and range of the multimeter determines the resolution. My results are shown in Table 1. The last three coaxial cables are from a cable chart. The resolution becomes worse on longer wires because the multimeter changes ranges to accommodate the higher capacitance (note the readings on 1,000 foot reels). Of course, this is still not bad — 54 inches out of 4,500 feet.

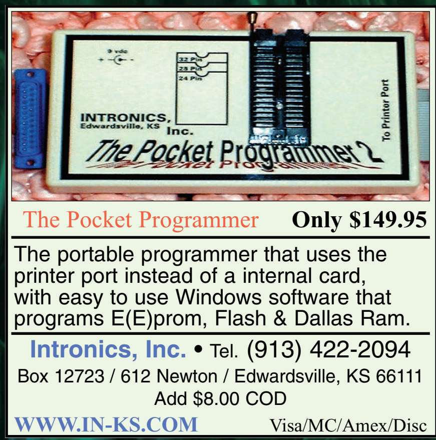
I know the next time I have an open wire in a wall or an area that is hard to examine, I will grab my multimeter. Before I make an installation, I will use my multimeter to insure that there is enough wire on the spool before I start. **NV**

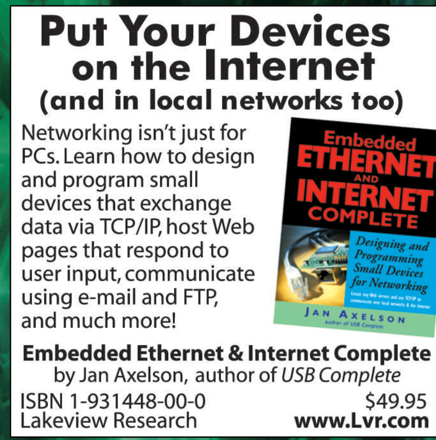
Type	Total Capacitance	Total Length	Cap./ft	Resolution (inches)	Range (feet)
Two pair twisted 18 gage	4.10E-08	1,100	3.73E-11	32.20	2,682.93
16-3 sj	1.00E-10	5	2.00E-11	6.00	500.00
Cat 3 phone wire, PVC	2.16E-08	1,000	2.16E-11	55.56	4,629.63
Cat 3 phone, plenum	2.21E-08	1,000	2.21E-11	54.30	4,524.89
14-2 nmb	5.26E-09	250	2.10E-11	5.70	475.29
18 gage speaker (pot)	9.10E-10	30	3.03E-11	3.96	329.67
24 gage speaker (pot)	1.69E-09	75	2.25E-11	5.33	443.79
16 gage sp. (pot)	9.80E-10	30	3.27E-11	3.67	306.12
RG-6	4.70E-10	25	1.88E-11	6.38	531.91
Twin lead, 20 gage	6.80E-10	100	6.80E-12	17.65	1,470.59
RG 8			2.95E-11	4.07	338.98
RG-25			5.00E-11	2.40	200.00
RG 59			2.10E-11	5.71	476.19

Table 1

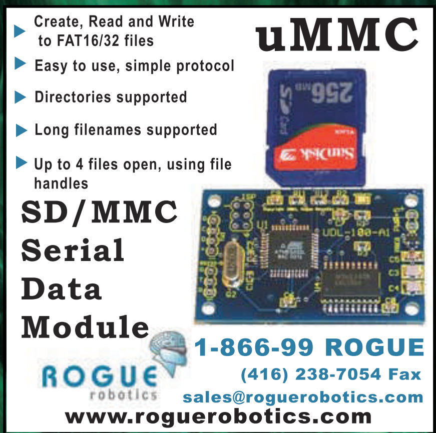


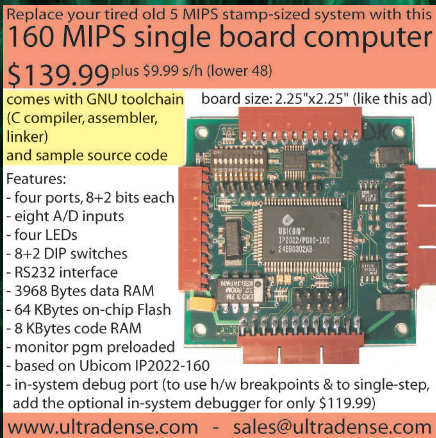






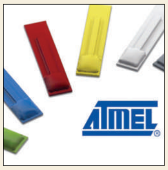
Electronics Showcase





News Bytes

Let Your Fingers Do the Talking



Biometrics — the science of using biological properties to identify individuals — will soon end up on your desk, most likely right on your computer keyboard. Retinal and fingerprint scanners are the last line of defense for network (and Internet) identity verification. Unlike passwords, you can never forget your genetically-encoded characteristics.

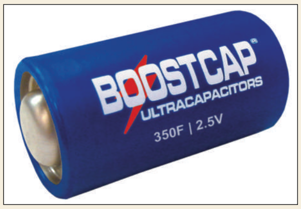
Atmel has announced extensions to its FingerChip™ line of fingerprint sweep sensors, allowing greater integration into portable electronic devices — like cell phones and PDAs. A sweep sensor is a rectangular thermal imaging array — 8 x 232 pixels in the case of the FingerChip — that creates a large 2D image as you slide your finger across it. Built-in hardware tracks the fingerprint motion and also decodes other actions — like taps and navigation gestures — turning it into a reverse desktop mouse of sorts.

Not only will future portable devices sport a "seamless" control interface, but they'll likely make sure you're really the one using it and buying those Barry Manilow LPs from eBay. For more information on Atmel's developments in biometric sensing, visit **www.atmel.com/products/Biometrics/**

350 Farads — Inconceivable!

Actually, it's just staggering, but that's the capacity of Maxwell Technology's new BCAP0350 Boostcap™ product. In a clever twist, the engineers at Maxwell have designed the 0350 to the same physical specifications as a common D cell battery, opening the door to many new applications, while simultaneously cutting the manufacturing cost (the price to hobbyists is expected to be around $20.00 each). The BCAP0350 will tolerate over a half million cycles and — with an ESR of only 3.2 milliohms — it is rated at 20 amps for charge/discharge current.

The BCAP0350 works in tandem with batteries for applications that require both a constant low power discharge for continual function and a pulse power for peak loads. In these applications, the device relieves batteries of peak power functions, resulting in an extension of battery life and a reduction of overall battery size and cost. For more information on Maxwell's ultracapacitor technology, visit **www.maxwell.com/ultracapacitors/**



Microcontrollers Are Great

But Don't Pass Up Conventional Electronics

Microcontrollers are great, especially the ones that are on the market today. They let you easily control devices and gather input from other devices with simple programs and circuits. However, not every application needs to use a microcontroller. Yet, many times people use one in a project when it is not necessary to do so. For instance, microcontrollers have been used to accomplish such simple tasks as blinking an LED. This is a fine thing to do with a microcontroller; however, it is overkill. It is synonymous to using a table saw to cut a piece a paper when a standard pair of scissors will do the job just fine.

Many beginners to microcontrollers and electronics overlook the basics of electronics and do not realize they can accomplish the same goal by using conventional methods. If you use conventional electronics, as opposed to a microcontroller, you may end up using a few more resistors and capacitors, but your project will probably end up costing you much less. In addition, you will not have to write a program and you will learn a little bit more about the fundamentals of electronics.

I'll show you two examples of circuits that do not use a microcontroller, but are many times built with one. I will also briefly explain some of the logic and theory behind these circuits. Hopefully, you can incorporate these examples as they are or — at the very least — they will give you ideas of your own. These examples not only will help replace the microcontroller in a simple project, but they are also helpful in offloading some of the work your microcontroller would do in a big project.

Lots of Little Lights

Every project needs to have several — if not many — blinking LEDs. Making an LED blink is probably the first thing you did when you learned how to use your microcontroller. Fortunately, blinking an LED is very easy to do with the use of conventional electronics, as well. I will show you how to alternately blink two LEDs using conventional electronics.

BY DUSTIN CHRISTOPHERSON

Flip-Flops and RC Circuits

There are many different ways that this can be accomplished, but the easiest way that I have found is by using what is called a flip-flop. Flip-flops are used all the time within nearly all digital integrated circuits, including microcontrollers. A flip-flop basically takes the output state from one logic circuit and feeds it into the input of another logic circuit. Then, the output from that logic circuit feeds into the input of the first logic circuit. In this way, the output of each logic circuit is dependent upon the other's previous state. There are many different types of flip-flops and there is much more information easily found on the different types and how they are used.

In addition to the flip-flop, you need some way to trigger the logic circuit (flip-flop); you can do this with an RC circuit. Capacitors really aren't very useful by themselves. On their own, they are pretty much only good for filtering A/C voltage (and shocking your friends), but — when used in conjunction with a resistor — they become very useful little devices. By putting these two devices together, you can create an RC circuit.

There are two types of RC circuits: integrators and differentiators. When a voltage is applied to an RC circuit, the capacitor "fills up" with energy. Then, when the voltage is taken away, the resistor "drains" the capacitor. The time it takes to "fill" and "drain" the capacitor can be measured in seconds and is called the RC time constant. Adjusting the values of either the capacitor or the resistor in an RC circuit allows you to adjust this RC time constant. The real difference between the integrator and the differentiator is in the way that the output behaves. These differences are shown in Figure 1.

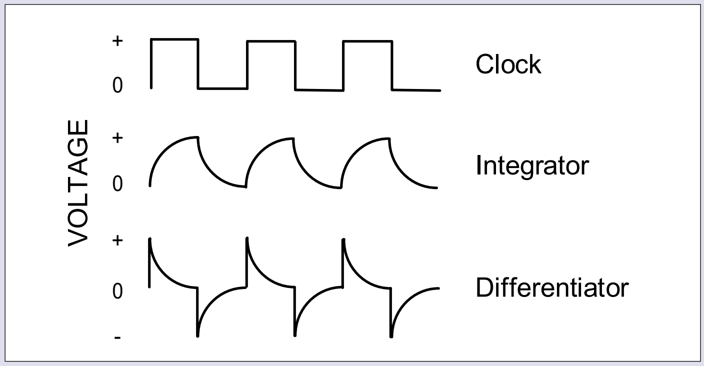


Figure 1. Differences between an integrator and a differentiator.

Using the flip-flop and the RC circuit, you can create a basic circuit that will alternately blink two LEDs. I used the RS (RESET–SET) type because it is the most basic flip-flop and it fits my needs perfectly. I used the differentiator RC circuit because it has the best output for triggering digital logic circuits. If you add a few LEDs and more resistors, you will have a circuit that will alternately blink two LEDs. This circuit is shown in Figure 2.

NAND Gates

The logic circuits I used to create the RS flip-flop are NAND gates. You can learn more about NAND gates — as well as many other basics of digital electronics — at **www.play-hookey.com** For now, however, it is sufficient to understand that a NAND gate's output only goes high when its two inputs are low. So, when you first apply power to the circuit (Figure 2), one of the two NAND gates (depending on which one is faster) will set its output high.

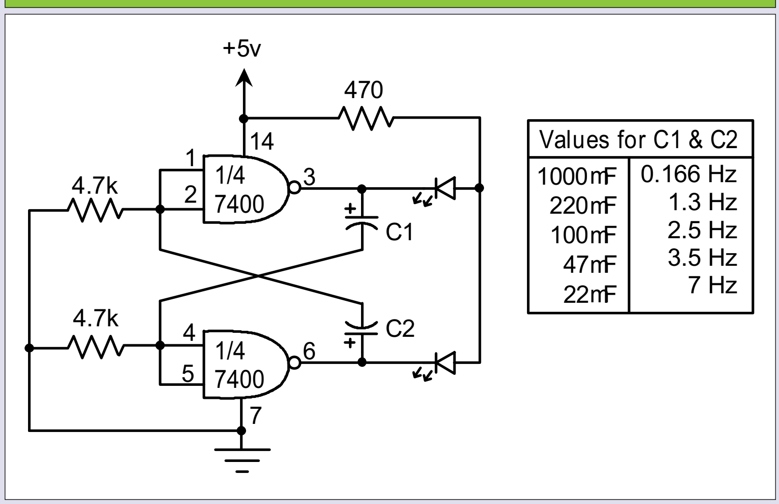
This will feed power to the differentiator that is connected to the output of the first NAND gate. This will send a digital "1" to both inputs on the other NAND gate, thus making its output low (turning off the second LED). The first LED will stay lit until the voltage output of the differentiator goes to near zero. At this time, the output of the second NAND gate will go high (turning on the second LED), thus sending the outputs of the first NAND gate to low (turning off the first LED). This process will go on as long as power is applied to the circuit and nothing in the circuit breaks.

Using the Circuit

To adjust the timing of the blinking LEDs, you can experiment with different values for the two capacitors. Higher values will increase the delay and lower values will decrease the delay. If you want both LEDs to be lit for equal amounts of time, then use the same values for both capacitors. You might try different values and see what kinds of results they give. You might also try using different values for your resistors to see what kind of effects they may have.

Building a circuit like this with a microcontroller would hardly require any external parts, but you would have to give up two of your microcontroller's output pins. In a big project, two pins can be quite costly and, even though you may need a few extra parts, this circuit will save these two

Figure 2. Flip-flop circuit that alternately blinks two LEDs.



pins. If all you need is a circuit that alternately blinks LEDs (like for a railroad crossing sign for your model train track), then this circuit is perfect for you. Also, it will probably only cost you a couple of dollars and you won't be putting your microcontroller to sleep.

TEMPERATURE SWITCH

Getting temperature readings is a very common thing for any electronic hobbyist to do. You may have a project in which you want an alarm to sound if your freezer rises above a certain temperature or you may want to be able to know if something gets too hot (like the inside of a case). This can easily be done with a microcontroller, but you can also do the same thing with a few conventional electronic parts.

TEMPERATURE PROBE

The first thing that is necessary when trying to read a specific temperature is a temperature probe. Temperature probes can usually read a range anywhere from -50°F to over 300°F. Most of them give an output in voltage that is linearly proportional to the temperature of the probe. These temperature probes are already calibrated and are guaranteed to be accurate. Some read the temperature in Fahrenheit and others in Celsius. The one that I chose to experiment with is the LM34DZ. It can operate on a supply voltage from 5 to 30 volts and measures temperatures from 32°F to 212°F and each degree of change will alter the output by 10 mV.

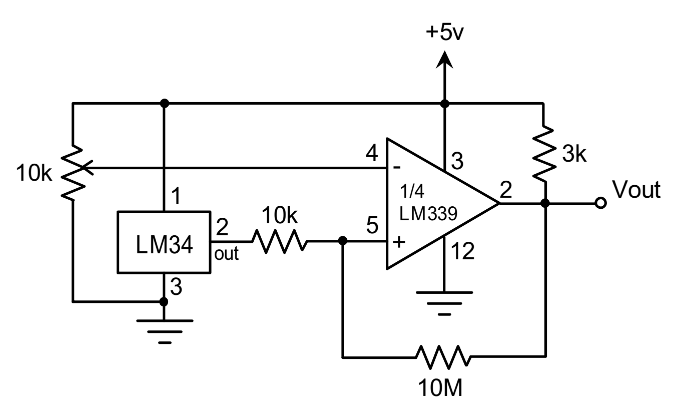
THE COMPARATOR

The LM34 will output a specific voltage for each degree of temperature. In order to detect a specific voltage from the LM34, you need a comparator. I used the LM339 quad comparator because it is very common and I had one lying around, but you could use any one of the many comparators on the market today. The LM339 actually has four comparators onboard, so you can do some fancy stuff with it if you want to, but I only used one of the comparators for my circuit.

A comparator has two inputs and one output. One of the inputs is set as a reference voltage and the other input is the voltage you want to compare with the reference voltage. If the input voltage reaches the reference voltage, it sets the output to high. For instance, let's say that you want to know when a particular input reaches 6 volts or more.

In this case, you would set your comparator to non-inverting and set your reference voltage to 6 volts. Then, when your input reaches 6 volts or more, the comparator will set the output to high. You can now read this output and trigger another circuit, like an alarm, LED, etc.

Figure 3. Temperature switch circuit.



PUTTING IT TOGETHER

You can put these two devices together and come up with a really great temperature switch. The complete temperature switch is shown in Figure 3. This circuit is very simple to build and easy to use.

Once the power is supplied to this circuit, you can read what the voltage is at the output (pin 2) on the LM34. You can use a voltmeter to do this. Place the positive probe from the voltmeter to pin 2 of the LM34 and place the negative probe to ground. This will give you an output voltage that corresponds to room temperature, providing a good reference point from which you can figure out what the voltage will be for a given temperature. On the LM34, each degree change in temperature will change the output voltage by 10 mV. Use this relationship to figure out the reference voltage that you need, based on the reference temperature you want.

Now, you can adjust the potentiometer so that the reference voltage on pin 4 of the LM339 equals the reference voltage you want (which corresponds to a specific temperature). If you need better accuracy in adjusting the voltage, you can use a potentiometer with a higher value. You can stop adjusting the reference voltage once you read the level you want. If the reference voltage is not going to change, you can replace the potentiometer with suitable fixed resistors.

AN EXAMPLE

Let me give you an example of how to accomplish this. Let's say you want to know when it reaches 100° outside. The first thing you do is read what the output is on the LM34 at room temperature. Let's say that your voltmeter reads 2.34 volts when the temperature is 72°. Now, figure out the difference between the two temperatures, which is 28°. Take this number and multiply it by 0.01 (10 mV change for each degree of change) and you get 0.28. Then, add this number to 2.34 and you get 2.62. This is the voltage that your reference voltage must be set to. Adjust the potentiometer until the output reads 2.62 volts and then stop. Your temperature switch is ready to go.

Trying It Out

Once the temperature switch is calibrated for a specific temperature, you can test the switch by heating the LM34 with a hair dryer. You can hook up an LED on the output (Vout). Once the temperature reaches the specified point, your LED should go on and stay on until the temperature drops again.

Just like the flashing LEDs, this circuit is relatively easy to build without a microcontroller. You can use this circuit as it is or modify it to suit many different purposes that you may have. You can also learn a great deal about how comparators work. At the very least, it will hopefully spur many ideas on how you can make comparators work for you.

Easy as Pie

These two circuit examples can be used as stand-alone circuits or they may be used in conjunction with other circuits. They can completely replace the use of a microcontroller. At the very least, these circuits can take a significant load off of your microcontroller-based project. The examples I have shown you are only part of what is available for the electronic hobbyist; they are only my ideas and certainly there are many others.

My advice to anyone getting started in microcontrollers and electronics is to get a breadboard, some basic electronic parts (get a grab bag or two), and start experimenting.

To start experimenting, keep reading *Nuts & Volts* and grab a book or two on the basics of electronics. Some of the best books I found for beginners are the Forrest Mims books from *RadioShack*. My Forrest Mims book is very old and beat up, but it's never very far from me when I experiment. There are also some really great websites out there that can help. Just like I said at the beginning of this article — microcontrollers are great! Try not to use them as a crutch and, instead, use some of those conventional electronics that have been around for years. Happy project building! **NV**

About the Author

Ever since I was about 10 years old, I have been interested in electronics. I went to school to become an electronics engineer, but decided to keep my electronics interest as a hobby instead, so I went into computer programming. Currently, I am a web developer and I love what I do. My favorite electronic device is the microcontroller because it involves my two loves (electronics and programming).

Selecting an Inexpensive LOGIC ANALYZER

"You can tell the difference between a professional and an amateur by the tools they use," or so the saying goes, but even pros have a limited budget. So, you only buy the tools as you need them. Sometimes, you only need a tool for a short period of time or just for one project. So, when you need a specialty tool, do you rent, borrow, or buy? If you need a full set of features, it might be cheaper to lease the equipment. Alternatively, you might want to buy an inexpensive device if it satisfies your immediate requirements.

The Problem

I'm more of a software person, but I work on embedded systems, so I do get to work with hardware. I was working on a project that required the use of a logic analyzer. I had never used a logic analyzer before, so I had to do a bit of research to understand what I would need before making the lease versus purchase decision. I'll first briefly introduce the project, so that you know the scope of the requirements. Then, I'll consider leasing as an option. Finally, I'll give a brief overview of the products that I considered and, ultimately, the product that was purchased.

The Project

The project involves the conversion of three-phase power with variable voltage and frequency to 60 Hz three-phase power (the grid). A piece of the hardware involves all digital signals for input and output. I won't go into the details of the project, but the hardware consists of eight switches, six phase polarity detector circuits, and a current zero crossing detector circuit for a total of 15 logic signals in the 0-5 volts range. Since I was developing the switching algorithm, I needed to examine and record all of these signals to determine if the device was performing properly.

The Requirements

Before looking for a logic analyzer, I needed to determine my data acquisition requirements. The 15 logic signals, eight switches, and the current zero crossing signal never change faster than 50 kHz. Also, the six phase signals change much more slowly — less than 200 Hz. I want to monitor these signals while the amplitude and phase of the input power change. Thus, I need to be able to look at an entire switching sequence for several seconds. Assuming a sample rate of 50 kHz for all 15 signals for four seconds, my worst case data buffer calculation is:

$$50{,}000 * 15 * 4.0 = 3{,}000{,}000 \text{ samples}$$

I'm currently working with a fixed input amplitude and frequency, so my immediate needs are only for one full 60 Hz cycle or about 16.7 milliseconds worth of data:

$$50{,}000 * 15 * 0.167 = 12{,}525 \text{ samples}$$

The above estimates assume that all of the signals are sampled at the same rate — which might not be the case — but the estimates define the lower and upper bounds for the data buffer size. So, my minimum requirements are a buffer size of at least 12,525 samples and a sampling rate of at least 50 kHz. Additionally, I want to be able to get digital copies of the images from the logic analyzer so I can include them in reports. I needed any software to run on both Windows 2000 and XP Pro. My bench is already covered with equipment, so a small footprint is preferred.

Oh, and I'm not working on this project by myself, so it would be great if I could save the recorded data and Email it to someone else so that person could look at the entire recorded stream without being limited to just screen shots and without having to Email large files (tens of megabytes). I will need this piece of equipment for at least a month, but six months is a more realistic time period. Also, I don't want to spend a lot of time looking for and pricing this piece of equipment because I want to use it as soon as possible. So, vendors with prices on their websites and next day shipping are preferred. Lastly, I wanted to keep the total cost under $1,000.00 and ideally under $700.00.

BY DUANE MATTERN

Lease Versus Purchase

There are many equipment leasing companies out there. Unfortunately, they rarely list prices or the details of their equipment on their websites. Also, most of the logic analyzers for lease are the big expensive monsters with lease prices in the order of $500.00/month. My requirements were only for 15 channels, possibly 12 months, and under $1,500.00. This pretty much ruled out the lease option — at least for the full-featured logic analyzer. So, I ruled out leasing and went shopping.

Shopping

Where do you do your shopping? When I'm looking for electronics, I typically look in past issues of *Nuts & Volts Magazine* before doing a search on Google. Once I have a product name, I'll look in Google's Groups to see if anyone has made comments (good or bad) about the equipment. I have seen a number of ads for PC-based electronic equipment that uses USB for communication. In fact, I have been involved with the development of such equipment using the ICs from **FTDIchip.com** From ads in *Nuts & Volts*, I knew that USB-based logic analyzers existed, so I started my Google search with the keywords, "USB Logic Analyzer." That immediately brought up a number of items that I have summarized in Table 1.

Product Selection

All of the products in Table 1 would probably work for my application. From a software point of view, USBee looks neat because it has an application programmer's interface, which could be used to expand its functionality. However, it only had eight channels and I needed 15. Also, it uses USB 2.0, which my PCs support, but I have not yet used it. The equipment from Link Instruments was pricey when compared to the other devices. I ruled out the Ant16 because I thought the buffer size of 2,048 samples/channel wouldn't support my requirement of collecting data for several seconds.

I ended up selecting the DigiView DV1-100 device over the Janatek Lu LA-USB device because of the price and also because I hoped that the DigiView's hardware data compression would allow me to look at long time sequences of the switching data. Also, TechTools was the vendor for the DigiView equipment and I've done business with them in the past.

Table 1. Summary of USB Logic Analyzer Search

Name	# of Chs	Buffer Size	Sample Rate/ch	Comments	Price
Ant8/Ant16	16	2,048 samples/ch	500 MSa/s	500MHz Async, 100MHz sync	$299.00
TechTools DigiView	18	132,000 samples	100 MSa/s	w/data compression	$495.95
Link Instruments LA-4540	16 24	8@512k, 8@256k 16@256k, 8@128k	500 MSa/s 250 MSa/s	various models	$2,200.00
Janatek Lu LA-USB	16	1,048,000 samples/ch	200 MSa/s		$750.00-$1,100.00
USBee (a number of different models)	8	1 million samples up to available PC memory	24 MSa/s	USB 2.0 for max. rate	$395.00-$895.00

Figure 1. DigiView DV1-100 logic analyzer equipment.

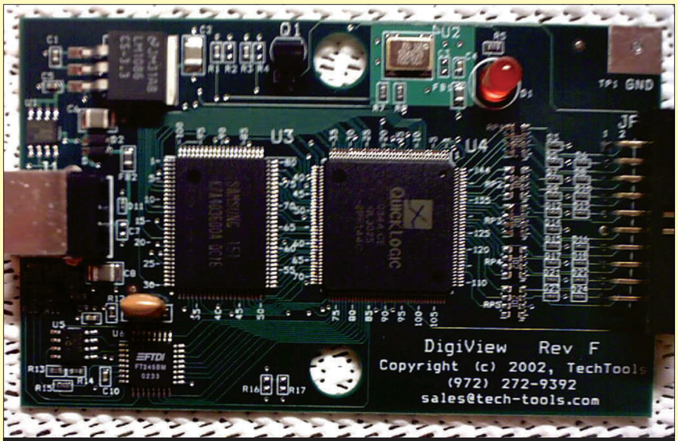


Figure 2. Inside the DV1-100.

DigiView DV1-100

I won't repeat the device specifications here. You can find the details of the device on the TechTools website. I'll just give a brief overview of my use of the equipment. I received the hardware within 24 hours of ordering it and it came nicely packed with all the pieces, CDROM, and a printed user's manual (see Figure 1). The product comes with micro-clip leads, but I have been using the raw connectors, which fit 0.025 inch square posts (stackable on 0.1 inch centers).

The DV1-100 has a screw panel on the back. I couldn't resist looking inside. The device consists of the FTDI FT245BM USB IC, a Samsung K7A403600A SRAM, and a Quicklogic QL3025 ASIC (Figure 2). You can download the software from the TechTools website. It uses an InstallShield installation procedure and the download includes the USB drivers. The printed manual appears to be identical to the online help, so, if you do download the software, you pretty much have everything except for the hardware. The software includes some test data, so you can examine the capabilities of the display.

The GUI

The main window shows the recorded data. There are pushbuttons for File, Help, Configure, Run/Stop, and Time, which is displayed in seconds, milliseconds, microseconds, and nanoseconds. The "File" menu allows the user to open, save, print, and exit. The Open/Save option allows the user to save data and Email it to someone else. The RUN button is disabled unless the hardware is detected. An example of a test sequence is shown in Figure 3.

In this display, I have zoomed out to show the change of the slower signals (three-phases at 100 Hz and three-phases at 60 Hz). I'm working out some noise issues with the hardware, so there is some signal switching where it shouldn't be. The software allows the user to zoom in and out on the data, center on the trigger, and set two snap lines that provide a measure of time between the two snap lines. Data files that I recorded were approximately 700 kbytes and compressing with ZIP reduced the file size by about 50%. This resulted in a file size that was easy to Email. This feature has been very useful for discussing results with the other team members that are working on the project.

The Configure pushbutton brings up a configuration window (Figure 4) that allows signals and triggers to be defined. A trigger can be assigned to any channel or combination of channels and can be level, edge triggered, or both, so you can trigger on multiple events. The wire color code is the same as the color code for resistors. This configure screen also allows auto save/restore and prefill to be enabled. The DigiView is always sampling and storing data in a circular buffer. This uses half of the capacity. When a trigger event occurs, DigiView fills the other half of the buffer or runs until the "Stop" pushbutton is pressed. Thus, the "trigger" event occurs at the midway point in the data. Time before the trigger event is shown as negative. Depending on how fast the data is changing, sometimes you have to press "Stop" because with compression, it can take several seconds to fill the remaining buffer. I found the software easy to use and intuitive.

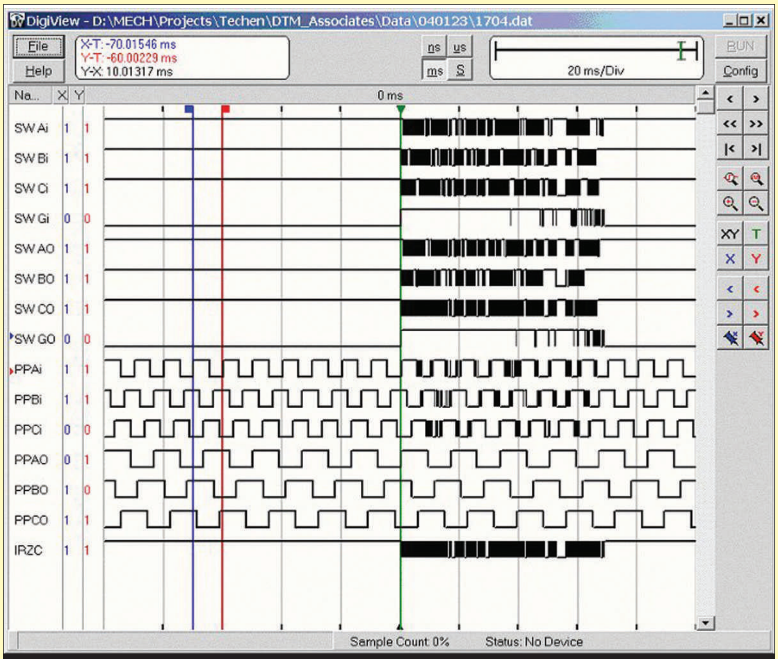


Figure 3. Main screen and data display.

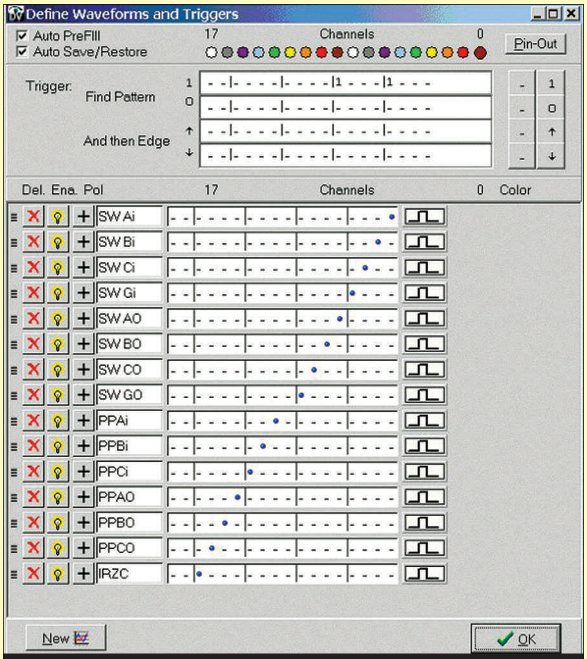


Figure 4. Configuration screen.

Summary

I've been able to record several seconds worth of data, which makes it much easier to examine what is going on. Once I get to the part of the project where I'm changing input voltage amplitude and frequency, this feature will come in very handy. All and all, I'm pretty happy with the procurement. It would have been heck trying to acquire all this data with a multi-channel scope. **NV**

Duane Mattern is a freelance engineer. He can be contacted via Email at d.mattern@ieee.org

RESOURCES

ANT
www.saelig.com/ANT16.htm
www.usb-instruments.com/hardware-ant16.html

DigiView DV1-100
www.tech-tools.com/dv_main.htm
www.hvwtech.com/pages/products_view.asp?ProductID=482

Link Instruments
www.linkinstruments.com/logana4.htm

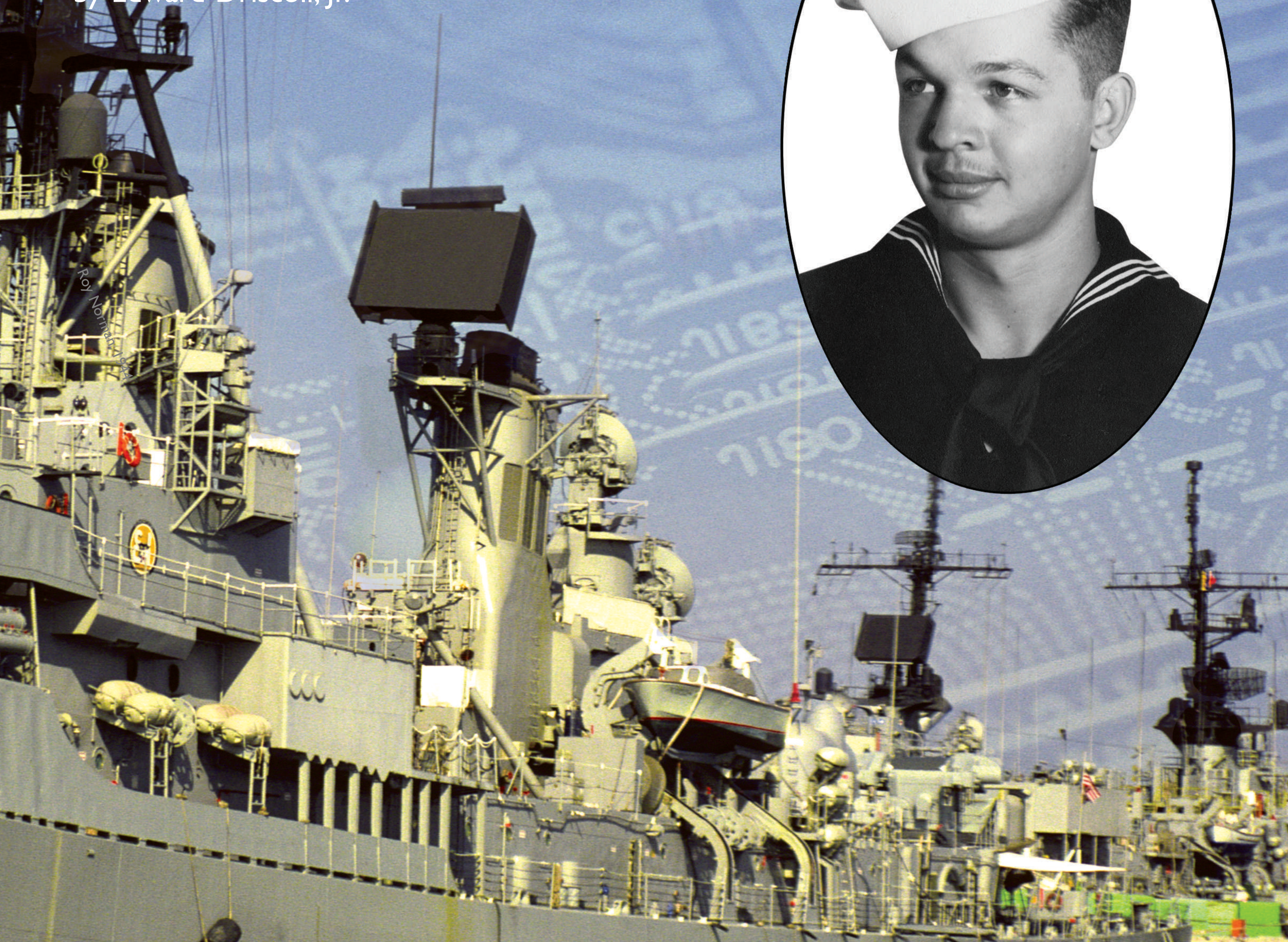
Janatek / Jobmatch
www.team-solutions.com/Products/External/JMPP/LuLAUSB/LuLAUSB.htm
www.tiepie.nl/pages/uk/lula.html
www.adept.co.za/~jobmatch/logic.htm

USBee
www.USBee.com/zx.html

Roy Norman

From the A-Bomb to the Enterprise

by Edward Driscoll, Jr.



For most of us, electronics is a hobby — a diversion from work and "real life." For 80-year-old Roy A. Norman, electronics has been his life.

It served him well with the US Navy; by 1948, he had already served for seven years. He was stationed in Guam, working his way up to the rank of petty officer first class, "getting rid of electronics equipment by throwing it over a cliff," when he got his orders to report to Sandia Base in Albuquerque, NM.

During World War II, Sandia Base had chiefly been the province of the Army Air Corps, which built Kirtland Air Force Base there at the beginning of World War II. In the late 1940s, the Navy began to use the area's wide open spaces to develop its nuclear program. It didn't hurt that it was in the same state as Los Alamos, the site of World War II's Manhattan Project.

"When we first got to the base, we had to fill out a long form for clearances so that we could work on the nuclear weapons. There was one time when the FBI was checking up on us and my mom wrote me to ask, 'What kind of trouble are you in now?!'"

Norman felt he couldn't tell her, "because I had some idea of what I was going to do." In May of '48 — when his security

clearance finally came in — he was driven out to the construction site where the rest of the company he was assigned to — Navy Special Weapons Unit number 471 — was working.

Sitting there was a partially assembled "Little Boy," the same type of atomic bomb that helped to bring victory to the US at the end of World War II.

"My division officer took me back to look at it and showed me what I was going to be responsible for. I went with him and another petty officer and we worked on a piece of electronics equipment that they hadn't been able to fix. It didn't take me but a few minutes to say, 'you've got a shorted out power transformer,' which they hadn't thought about.

"Then he assigned me to my other duties: Number one, maintaining all of the equipment and tools necessary.

"Number two, whenever he wasn't around, I was to insert the plutonium balls down into the weapon."

(Important safety tip to the younger readers of *Nuts & Volts*: Don't insert plutonium balls into atomic bombs without proper adult supervision. Trust me on this, kids.)

While the phrase, "insert the plutonium balls down into the weapon," conjures up *China Syndrome*-like mental images, Norman says it was actually much safer than how the phrase sounds.

"It wasn't dangerous. It *was* dangerous if you took two or three of the balls and put them up on the workbench at the same time; it might go critical on you, but they were all kept in little cages, so that they were separated by the proper distance. I never had more than one or two in the workshop at the same time."

So you weren't too worried that you'd end up as a stain on the desert floor?

"No, I wasn't, but, when I left there in February of 1951, the man who relieved me *was* afraid of the job. I believe he died, not too many years later. I called his wife when I went through Albuquerque in '62, I believe and she said that he had died of cancer, lost all his hair, and everything else.

"I knew he was afraid of the job. Plutonium oxidizes — it was a great alpha-emitter and, of course, if you got plutonium down in your lungs, they say that's a very great poison. We would rub the balls down with Kleenex and stick 'em under an alpha counter to see how active they were."

"But other than that," Norman says, "I never was afraid of them."

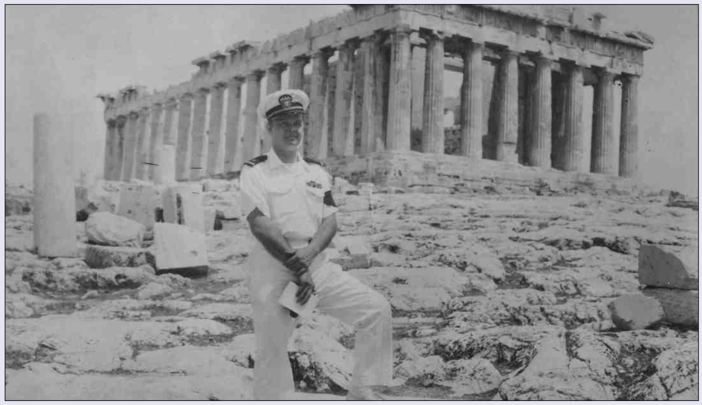
Preparing the First Carrier-Launched A-Bomb

During that time, Norman helped load the first aircraft that carried an atomic bomb from a naval aircraft carrier, the *USS Coral Sea*. "This was the first time I had been in the Atlantic Ocean. We assembled a couple of weapons, then came back into port and anchored out in Hampton Roads, VA. A whole bunch of VIPs came aboard and we went back out to sea.

"In the meantime, we had loaded a P2V aircraft, which was a two-engine aircraft that was too big to land on the carrier; it was lifted by crane up on the flight deck."

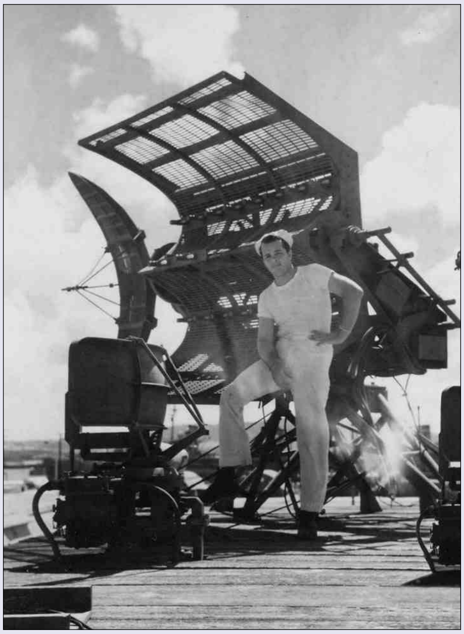
The P2V was the propeller-driven Lockheed Neptune, variations of which served the Navy until the late 1970s.

On April 21st, 1950, at 7:30 AM, it took off from the *Coral Sea*. Bomb and all, the plane weighed 74,668 pounds and, in addition to being the first plane to be carrier-launched with an atomic weapon, it was also the heaviest aircraft ever launched from an aircraft carrier up to that point. It was so heavy and the *Coral Sea*'s was deck too short for it, so the Neptune required JATO (Jet Assisted Take Off) bottles to get it airborne. (Norman has a page on the *USS Coral Sea*'s website devoted to the launch:



Athens, Greece

1944 USS *Sirius* "Final Tubes for IBM + TauXmtrs"



1947 Guam Island Fire Control Radar Antenna

Nevada Test Site, 1951

www.usscoralsea.net/pages/nuke.html)

Following the launch, Roy Norman and his men went below deck where the VIPs onboard reviewed the various components of the Neptune and its special cargo. "I had a lot of questions thrown at me," Norman recalls, "until the *Coral Sea* returned to port in Hampton Roads later that day."

"It Worked *Damn* Well, Let Me Tell You"

Norman wasn't quite through with atomic weapons. A year after the Neptune launch, the Navy sent him out to Enewetak. It was April of '51.

Enewetak is an atoll in the Marshall Islands chain, 2,500 miles southwest of Honolulu, HI. "There, I witnessed two atomic bomb explosions and the first attempt at a hydrogen bomb explosion."

The hydrogen bomb tests came about as a result of fears in Washington that the US was being overtaken in the nuclear arms race by the Soviet Union. The first Soviet fission bomb had been revealed in the fall of '49 and Klaus Fuchs' espionage activity at Los Alamos, NM was discovered in January of the following year. Needless to say, the Cold War tensions were escalating. On January 31, 1951, Harry Truman announced America's plan to build an H-bomb.

While the Marshall Islands' Bikini Atoll has gotten the lion's share of publicity because of its role as the first site of nuclear testing in the South Pacific, Enewetak was better situated to accommodate the large aircraft needed to move the materials and the 11,000 men needed for the hydrogen bomb test, which was code named "Mike Shot." Mike was code for megaton — 10.4 megatons, in this case.

Norman says, "It worked *damn* well, let me tell you!

"We had a 225-kiloton explosion from that one and I think I was only about 17 miles away from it when it went off. And it was quite a thing to see — and hear, too."

Mike lit up the Pacific sky with a

blazing red fireball. “The sand was melted about an inch thick. In fact, an Army six-by could drive on it. It surprised me because I had been down to the Trinity site where the first one had been tested back in ’44. I went down there on the 19th of July in 1949, and it was only crusted about a quarter of an inch thick and it was dark green in places from the minerals in the soil there, whereas the one out in Enewetak was all yellow because there weren’t any minerals there, other than coral sand.”

Dress Whites, February 1952

Last Honors upon Retiring

Report to the *Enterprise*

Norman left the Navy’s nuclear weapons program about a year later, with the rank of warrant officer. In May of ’52, he was transferred to the *USS Pittsburgh* and, eventually, to the Navy’s Bureau of Ships, whose Washington, DC building was located where the black marble Vietnam War Memorial is located today. At the Bureau of Ships, he worked on harbor defense, traveling across the country on waterfront inspections.

Eventually, he was commissioned as an ensign and, in April of 1961, he was ordered to report as electronics material officer to a ship that had just been commissioned by the Navy the year before: the *USS Enterprise*.

“I was responsible for the maintenance of all of the electronics equipment associated with the ship (not on any of the aircraft, though). That was a major job in itself.” For this major job, Norman had 62 men working under him. “Up in ‘the island’ of the *Enterprise* — the square superstructure above the flight deck — each side of that ship had two separate radars. One was a low frequency one that was for long distance searches and the other one was a rather higher frequency one — about 33,000 or 34,000 megacycles. That was a fixed array thing and there was one on each square. So, I had eight, three-megawatt radars and I had a whole bunch of men to take care of it to keep it operating, plus all of the communications and navigation equipment for the ship.”

“How Would You Like to Go to London?”

Eventually, Norman put in for service in West Germany, where a friend of his was stationed. He was turned down by the Navy, which made him a counter-proposal: “How would you like to go to London?”

“That was a *great* tour of duty,” Norman says without hesitation. “In July of 1964, my wife and the kids and I got transferred to London and I was on a four star admiral’s

Arriving home after 30 years of Service

Civilian Norman at Savannah, GA Laboratory

staff — Admiral McCain, the father of the now Senator McCain. I was on Admiral McCain's staff as an electronics warfare officer for four years.

"Afterward, since I only had about a year and a half to do, they transferred me back down to the Brunswick Naval Air Technical Center in Georgia and I spent my last year and a half here. I retired on the last day of January, 1972." Norman retired with the rank of lieutenant commander. "I've now been retired for 32 years, plus."

After the service, Norman received honors in chemistry at Brunswick College, then worked for a couple of different companies in jobs that combined his backgrounds in electronics, chemistry, and maritime knowledge.

Today, he's fully retired, "mainly because of health reasons. I'm almost 80 now and I've had two brain tumor operations and I seem to be functioning all right, except for my legs — arthritis in the knees."

Two brain tumor operations? Could they be related to ...

"No sir. I asked the doctor about that and he said, no, he didn't think so. They were non-cancerous-type brain tumors."

But that's in the past. At 80, Roy Norman is able to look back at a life in technology and say it was not a bad one at that.

Roy Norman can be reached via Email at usnmustang1@bellsouth.net **NV**

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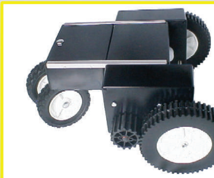

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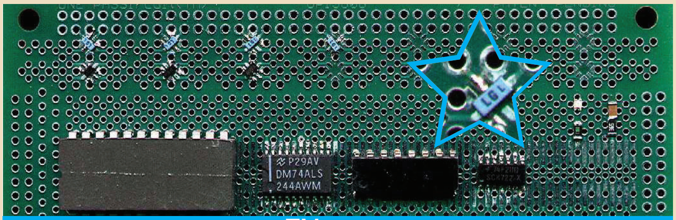

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Advanced Technologies

Bypass Surgery via Robotic System

The da Vinci® Surgical System in the operating room of St. Pierre Hospital, Brussels, Belgium. Copyright 2004, Intuitive Surgical, Inc.

Let's say you've lived on pizza, double cheeseburgers, and potato chips for the last couple decades and your aorta has begun to look like a radiator hose stuffed full of cottage cheese. The traditional solution is to pry open your rib cage and splice in a new piece of artery to bypass the plugged one, which is highly unpleasant and occasionally fatal. Now, your prospects may have improved.

For several years, Ventrica, Inc. (**www.ventrica.com**), and Intuitive Surgical, Inc. (**www.intuitivesurgical.com**), have been collaborating in an effort to develop a simpler, less traumatic approach. Earlier this year, the collaboration bore fruit when Ventrica's Endo MVP® Distal Anastomotic Device was employed as a component of Intuitive's da Vinci® Surgical System and was successfully used in a closed-chest coronary artery bypass procedure.

The device was inserted through small incisions in the patient's chest, thereby minimizing physical trauma. It was then deployed into the internal thoracic artery and a coronary artery to create an anastomotic connection to bypass the blockage. The technology is described as a proprietary coupling method that uses magnetic attraction to form a self-sealing connection between two blood vessels.

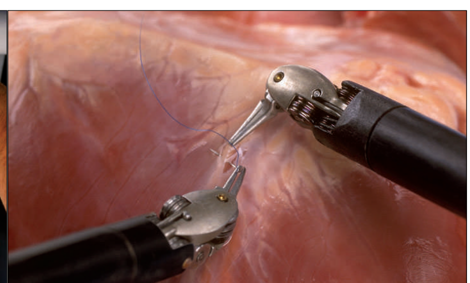
According to a Ventrica spokesman, "The development of technologies such as the Endo MVP System represents a major break-through in providing surgeons with the ability to perform beating heart surgery through small ports or incisions in the chest, thus reducing patient pain, trauma, and recovery time."

The surgeon actually performs the operation remotely from a console that employs a 3-D viewer and master controllers. Normally, the console is located a meter or two from the patient, but there is no particular reason why it cannot involve greater distances.

For example, if the equipment was installed in a golf cart, the surgeon could tee off while you were being prepared for surgery and perform the operation while in the rough on the fourth hole. He might have to allow a few other golfers to play through, but no one ever said that a career in medicine didn't involve sacrifices.

In any event, the da Vinci system is now approved by the US Food and Drug Administration and is being deployed in hospitals in the US and Europe. Fourteen were sold in the first quarter of 2004 alone, so there may be one near you. Approximately 700,000 bypass procedures are performed each year in the US alone, so there is no shortage of potential patients.

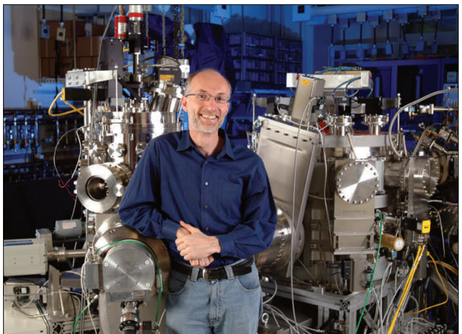
The system can also be used for mitral valve repair, gastric bypass surgery, radial prostatectomy, esophageal surgery, and other procedures.



Ventrica's EndoWrist® surgical instruments and console master controls. Copyright 2004, Intuitive Surgical, Inc.

New Spin on Electronics

IBM (**www.ibm.com**) and Stanford University (**www.stanford.edu**) have joined forces in an attempt to create a new breed of high-performance, low-power electronics in the emerging field of nanotechnology called "spintronics." To formalize the effort, scientists at IBM's Almaden Research Center and



Harnessing the power of electron spin is the goal of IBM Fellow Stuart Parkin, shown with a six-chamber, $5 million high-vacuum apparatus used to mix and match nanotech materials manufacturing techniques and analyze the results. Photo courtesy of International Business Machines Corp. Unauthorized use not permitted.

Stanford University have formed the IBM-Stanford Spintronic Science and Applications Center (SpinAps, for short).

Electron spin is a quantum property that has two possible states: "up" or "down." Aligning spins in a material creates magnetism.

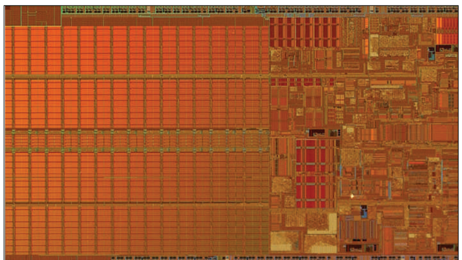
Moreover, magnetic fields affect the passage of "up" and "down" electrons differently. Understanding and controlling this property is central to creating a whole new breed of electronic properties. According to an IBM spokesman, "SpinAps researchers will work to create breakthroughs that could revolutionize the electronics industry, just as the transistor did 50 years ago."

In fact, the technology has already been put to a few practical uses. The first mass-produced spintronic device — introduced in 1997 — is the giant magnetoresistive (GMR) head developed at the IBM Almaden lab. This super-sensitive magnetic-field sensor has enabled a 40-fold increase in data density over the past seven years. Another multilayered spintronic structure is at the heart of the high-speed, nonvolatile magnetic random access memory (MRAM) that is currently being developed by an IBM-Infineon collaboration and several other companies.

SpinAps scientists envision creating new materials and devices with entirely new capabilities (e.g., reconfigurable logic devices, room-temperature superconductors, and quantum computers) that would create dramatic, new computational models. However, commercial products from the ongoing research are not expected for at least five years.

Computers and Networking

New Mobile Processor from Intel



Pentium® M processor die. Courtesy of Intel Corporation.

Intel Corporation (**www.intel.com**) is shipping three new Intel® Pentium® M processors, aimed at boosting the performance of Intel Centrino mobile technology. Formerly code-named Dothan, the Intel Pentium M processor models 735, 745, and 7553 are built on Intel's high-volume 90 nm manufacturing process technology, which produces smaller, faster transistors. They are manufactured on 300 mm wafers, which provide more than double the capacity of the earlier 200 mm wafers.

Based on Intel's mobile micro-architecture, the new processors are said to boost performance by up to 17% (as compared with the previous generation processor), with 2 MB of integrated, power managed, level 2 (L2) cache, micro-architectural enhancements, and frequencies up to 2 GHz. With the new processors and the recently introduced Intel PRO/Wireless 2200BG network connection, the technology enables improved high definition video playback, faster application response, better multi-tasking, and higher bandwidth wireless data transmission.

Socket-level compatibility with the previous Pentium M processor generation allows OEMs to build the new components into existing system designs. All three processors support Enhanced Intel Speedstep® Technology, which helps optimize application performance and power

consumption to enable longer battery life. Prices are $637.00 for the 2 GHz model 755, $423.00 for the 1.8 GHz model 745, and $294.00 for the 1.7-GHz model 735.

Burn 8.5 GB on One DVD

Sony's new double layer DVD drives allow storage of up to 8.5 GB. Courtesy of Sony Electronics.

Sony Electronics (**www.sony.com**) has added two DVD+R double layer (DL) DVD drives to its family of dual RW burners. The internal DRU-700A and external DRX-700UL drives mark Sony's entry into double layer recording.

Nearly doubling the storage capacity of current DVD recordable discs, these DVD drives allow users to record up to four hours of MPEG-2 video or up to 8.5 GB of data, music, or images on compatible DVD+R DL media.

DVD+R DL discs are single-sided with two information layers that can be independently written and accessed. Both layers can be accessed from the same side of the disc, so there is no need to turn the disc over during recording or playback. DVD+R DL discs are also compliant DVD9 discs, so they are compatible with most consumer DVD video players and DVD-ROM drives.

The internal DRU-700A drive comes with an ATAPI interface for easy installation inside a PC and includes a black replacement bezel for those with black-colored PC cases. The external DRX-700UL drive features a space efficient design and offers connectivity with both i.LINK® (IEEE 1394) and USB 2.0 interfaces. The internal drive will run you about $230.00 and the external is $330.00. They are slated to be available by the time you read this.

Circuits and Devices

Microphone Enables Long Distance Pick-Up

The Voice Tracker™ microphone is designed for recording in large areas. Courtesy of Acoustic Magic, Inc.

If you need to create transcriptions of meetings in offices or conference rooms, you might be interested in the Voice Tracker™ microphone — a product of Acoustic Magic (**www.acousticmagic.com**).

According to the vendor, it locates a talker and electronically steers a "listening beam" — like an acoustic searchlight — in that direction. This creates spatial filtering, such as sounds from other parts of the room are not picked up. In addition, digital noise reduction algorithms remove background noise.

This two-stage noise reduction, coupled with increased sensitivity provided by eight microphone elements, results in improved range and sound quality. The Voice Tracker can scan a full 180° and can steer from one talker to the next in a few milliseconds. It can be connected directly to a handheld recorder or to a PC through the sound card USB port (with an optional USB adapter). Suggested applications include:

- Speech recognition for command and control of computers and PDSs in noisy environments
- Speech recognition for dictation without the need of a headset microphone
- Hands-free digital recording in large rooms
- Teleconferencing

The microphone is certified for use with IBM's ViaVoice software and other applications. The price is $249.00, plus $54.00 for the optional USB adapter.

D/A Converter Clocks at 1.2 Gsps

As signal processing requirements increase in speed and complexity, electronic engineers are looking for data converters that can synthesize high quality signals at much higher frequencies. To address that need, Analog Devices, Inc. (**www.analog.com**), has introduced the AD9736, a new member of the TxDAC+® family.

Billed as the industry's first 14-bit digital-to-analog converter (DAC) to clock at a sample rate of 1.2 gigasamples per second (Gsps), the AD9736 provides a fast, low voltage differential signaling (LVDS) input interface using a double-data-rate (DDR) mode, which enables high conversion rates over a wide bandwidth.

This allows it to receive data at a high speed while maintaining low distortion and noise, simplifying the transmit signal chain and enabling high quality synthesis of wideband signals at intermediate frequencies up to the Nyquist rate (one-half of the DAC sampling rate).

In addition to its speed, the AD9736 features the low power dissipation, making it useful for applications that require a low power DAC to process high frequency and wide synthesis bandwidth signals. These applications include high bandwidth test and measurement equipment, automatic test equipment, radar, avionics, and wideband communications — such as point-to-point wireless, LMDS (local multipoint

distribution systems), and power amplifier linearization. The AD9736 operates from 1.8 V and 3.3 V supplies, consuming 380 mW at 1.2 GSPS with the interpolation filter bypassed and 550 mW with the interpolation filter enabled.

The device is offered in a 160-pin BGA (ball grid array) package to reduce parasitics and improve performance. Production quantities for the AD9736, AD9735, and AD9734 will be available at the end of 2004. In 1,000 piece quantities, the AD9736 is priced at $34.95; the pin-compatible 12-bit AD9735 is $19.95, and the 10-bit AD9734 is $14.95.

Industry and the Profession

BASIC Language 40 Years Old

2004 marks the 40th anniversary of the Beginners' All-purpose Symbolic Instruction Code (BASIC) computer language, devised at Dartmouth University by Profs. John Kemeny and Thomas Kurtz. Descended from FORTRAN and ALGOL, it was the first to use simple commands such as LIST, SAVE, RUN, END, and PRINT and it eventually became the world's most widely used computer language, thanks to outreach efforts that brought the technology to a network of high schools, colleges, and corporate partners. Although C++, Java, and other languages have more or less superseded Basic, variations — such as Visual Basic — are still used. *(I learned Basic in the seventh grade! – Editor Dan.)*

100 Million eMacs Ordered, 0 Delivered

For years, malcontented Macintosh users have opined that the machine's rather pathetic market share is the direct result of an inability at Apple Computer (**www.apple.com**) to control costs, which translates into prices that just don't fly for the average purchaser. It's simply a matter of price being inversely proportional to sales.

Back in April, this concept was dramatically underscored when Catena Corp. (**www.catena.co.jp**) accidentally offered eMac computers for sale on Yahoo! Japan at a price of $25.45 each. In less than 24 hours, the company reportedly received orders from about 20,000 individuals for a total of 100 million computers.

Sadly, the machines actually sell for a base price of about $800.00, so the orders were not filled, but — had they been — Apple would have achieved an instant 90% share of the Japanese market. Is there a lesson here somewhere? **NV**

Understanding, Designing, and Constructing Robots and Robotic Systems

Personal Robotics

Building Stuff

It sounds easy, but — for many of us — it is a major mental block. We dream and hope, yet cannot achieve. I go through the same thing when it comes to programming or writing, but the difference is, you can easily destroy something if you build it improperly, but playing with words and code is like playing with vapor. Like the old saying, "but words will never hurt me," code doesn't break like physical things do.

It really doesn't have to be that drastic, though. By using inexpensive materials and simple tools, we can build to our hearts' content, without fear of ruining what we are doing. In fact, I like to prototype with simple materials and — once everything works out well — you can transition to more complicated techniques. The tools and materials I will detail are appropriate for miniature robots up to about 8" cubed. For larger projects, some different techniques apply, as well.

Tap Handle

To begin, some simple tools are in order. You don't need to spend a lot; buy only the tools appropriate to the materials you wish to work with. I have provided part numbers to indicate a personal preference, preferring not to substitute other products. Your local hobby shop can help you here.

Speaking of hobby shops, my local hobby shop — **www.martyshobbies.com** — carries almost everything I need, but the most important things you will find at your local hobby shop are knowledge and wisdom. Support your LHS with your business and what you will get in experience will be returned 10 times over.

- X-Acto knife and lots of extra #11 blades
- Cork-backed, straight edge ruler
- Razor saw
- Miter box
- Pin vise and some drill bits
- Sandpaper
- Small round, square, and triangular files
- K & S tubing cutter
- K & S tubing bender
- Soldering iron
- Soldering gun
- Needle applicator for Plastruct
- Bondene adhesive
- Machinist's scribe
- Calipers
- Bow compass with two points
- Small through taps and tap handle, sizes 1-72, 2-56, and 4-40 (plus 6-32 and 10-24, if you are adventurous.)
- Bench vise or desk vise
- Small tweezers
- Wire cutters and strippers

For materials, we can start out with the following:

- Evergreen scale models "sidewalk" styrene 1/4" to 1/2" squares
- Styrene sheet, 0.040" thick
- Some Plaststruct shapes like "L" beams and square sections
- Double-sided servo tape
- Squadron putty
- Epoxy
- Thick and thin Cyanoacrylate adhesive
- Cyanoacrylate accelerator
- Polystyrene adhesive and needle applicator
- Brass tubing in increments up to 1/4"
- Graph paper
- Shrink tubing in various sizes up to 1/4" (or larger if you like)
- Colored ribbon cable

Before I guide you through a complete project, a brief description is warranted. This will help you understand the use of each tool and material.

X-Acto knife: By cutting through flat materials using a series of shallower cuts or by dragging the opposite side across the plastic to scribe, rather than cut, you can produce very accurate results. Remember, the first cut will guide your successive cuts. I personally only use the #11 blades, with the exception of, perhaps, the #213 and #215 saw blades.

Razor saw and miter box: This will help you make nice 90° or 45° cuts. Start by drawing the saw across the piece gently at first. Once the cut is started, you can get more

aggressive. You can cut plastic, metal, or wood with this combination. Make sure the miter box is deep enough for the materials you intend to work with and make sure the saw is deep enough for the miter box. A good choice is the X-Acto #75330 miterbox and #239 saw.

Pin vise: The pin vise will allow you to hold drill bits and other round shank tools. This way, thin plastics can easily be drilled by hand and sometimes this is better than plunging through things madly with a drill press — and it's safer, too.

Sandpaper and files: These can help you accurately and progressively remove material. Round files can help you enlarge holes and triangular or square files can help make a square hole or notch. Remember that files work by drawing them toward you and applying gentle pressure. Pushing in the opposite direction can damage a file if this is done on a hard material. Keep a wire brush handy to clean clogged files.

Sandpaper can clean up rough edges and square up wavy cuts. I prefer wet-sanding plastics. If you want to paint your creation, puttying and wet sanding can produce a mirror finish in painted surfaces. Buy a selection of sizes around 180 grit, with more selection toward the finer end if you intend to paint your creation. If you do plan on producing mirror-like finishes, start with something medium and establish a "grain" by only sanding in one direction. Always sand with the grain and progress to finer and finer grades of sandpaper.

Sandpaper can also be used to prep surfaces for epoxying. In this case, use a coarse grit and sand in multiple directions. For fine and wet work, I like Flex-I-grit from K & S, but other types are sufficient.

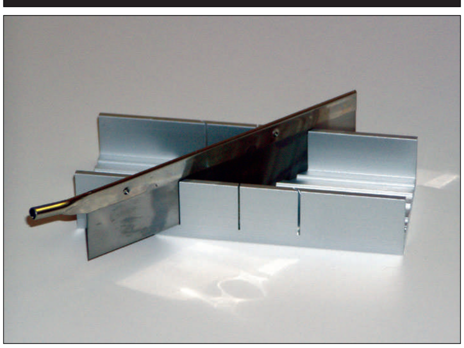
K & S tubing cutter: This is superior to a standard tubing cutter for small sizes of tubing. Make a mark with an ink marker at the distance where you want to cut off. Then, precisely scribe the exact distance you want. Set this in your cutter and tighten the adjustment until the wheel just touches. Tighten just a bit more and slowly turn the tube until it rotates loosely. Continue tightening and turning until it breaks. If you were gentle enough, there will be very little — if any — burr to remove. If you wish, a drop of light oil helps, too. A set of calipers can be ultra handy to get the exact distance you want.

If you plan on soldering brass tubing, it helps to clean it before you cut it, since small sections can be difficult to work with. Lightly buff it with steel wool or sand it before cutting to remove oxidization.

K & S tubing bender: These are a tremendous way to bend tubing without kinking it. You can also attempt to bend larger diameters by crimping one end, filling the tubing with sand or salt, and then crimping the other end until it is tightly packed. Perform your bends around steel posts in a vise.

Soldering iron: If you are going to build robots, you will be doing a lot of soldering. Here is where I choose not to skimp. I prefer a 42-watt soldering station from Weller. Here are a few tips for successful soldering:

- Use 60/40 rosin core solder. *Never* use acid core solder.
- The key to soldering is to keep the iron and sponge clean, with the sponge damp, but not soggy.
- Clean your iron every time you do a joint.



Razor Saw and Miter Box

X-Acto Knife

- Clean what you are soldering. PCBs can be gently cleaned with fine steel wool if they are not pre-tinned (solder-coated pads and races).
- Solder opposite the component side. Bend component leads to keep them in place.

To solder a joint, follow these steps:

- "Wet" the tip with a bit of solder.

- Touch the wetted tip to the thing you are soldering — usually the thing with the greatest thermal mass. Let it warm for a second, then feed more solder into the wetted area. At some point, the solder needs to flow on the components. If it does not, they may be dirty. Use the iron to bridge the gap to allow solder to flow to both components.

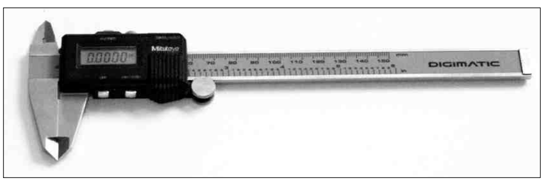
Pin Vise

Needle Applicator

• Once there is an appropriate amount of solder, remove the iron and hold the component still for a few seconds. Components in a board should be soldered in such a way that the solder flows across the whole pad, through the hole (if plated through), and across the opposite side.

• Frosty-looking joints are called "cold." A proper joint should be clean and shiny. If you are not getting proper joints, your temperature may be off.

Digital Caliper



Tap and Drill Set

• For soldering wires together, make the wires into two hooks, then twist the wires together. Follow up with solder and heat shrink. (Heat shrink is infinitely preferred, unless you intend to remove the joint in short order.)

Soldering gun: What goes for the iron goes for the gun. I use my gun in place of brazing. It is easier, but the joints are not as strong. It is also a must if you get into soldering your own tabbed battery packs or use heavy gauge wire. (Never solder non-tabbed batteries.)

Needle applicator for Plastruct Bondene: This allows you to apply very precise amounts of adhesive. I like the 20 gauge, 1" long needle. Remember to keep your adhesive stored with the thin wire in the tube to keep it from evaporating. Larger gauges can handle more viscous adhesives, like carpenter's glue.

Machinist's scribe: This is useful for marking cut lines on metal or plastic. You can also scribe multiple times and bend on the scribe line to cut many plastics.

Calipers: Calipers allow you to precisely measure external and internal dimensions to a high degree of precision.

A set of really cheap digital calipers can be had for about $20.00 these days, but, personally, I prefer not to skimp on measuring tools. I have had my Mitutoyo digital calipers for 10 years now and they were well worth the investment.

Bow compass with two points: This allows you to make cut-curved sections in styrene by gently and repeatedly scribing the cut you want. Remember to do the outermost diameters first on multiple cuts. Smaller diameter cuts may be tedious, but larger cuts are a breeze.

Small through taps: If you want to tap into brass or other metals, these are a must. You will have poor results with small screws in plastic, however. Taps require a drill of a certain size to "pave the way" before you cut threads. Taps can be bought in sets with the drills.

There are three types of taps: taper, plug, and bottoming. If you intend on tapping "blind holes" where the hole does not go all the way through the material, then progress through the three types, being extra careful with the bottoming. Otherwise, simply use the taper all the way through.

To tap a hole, first drill with the tapping drill, clear the hole of debris, then screw the tap into the hole, changing directions frequently to clear the tap. This is sort of like two steps forward, one back, as it were. The harder the material, the deeper you go; the smaller the tap, the more critical this is. Also, it is recommended that you should use tapping fluid on metals. When tapping blind holes, clean out the hole frequently.

Keeping the tap perpendicular to your work is important. If you have a drill press, you can remove the belt, chuck up larger taps, and manually drive the tap, but you must be careful. You must have a steady hand to do this with a small tap. You can also make a tapping guide by drilling a piece of material with the clearance tap.

Screw	Clearance	Tap
1-72	#48	#54
2-56	#43	#51
4-40	#32	#44

Those of you across the pond who are accustomed to the highly complicated, decimal-based metric system must now screw on your thinking caps, but I'll walk you through this. Take the pitch of your screw, subtract that from the diameter, and that is your tap drill size.

Bench vise or desk vise: This

is really a must. I personally do not have a bench vise, but my little Panavise does everything I need. Remember that the jaws of a vise can mar softer materials.

Small tweezers: These are really useful for picking up and positioning anything that is smaller than the distance between the tip of your index finger and thumb when pressed together. Here is another area where I don't skimp; a crappy set of tweezers is more of a frustration than anything else. I have had a set of tweezers from Grobet for about a decade and they continue to serve well.

Wire cutters and strippers: Wire cutters are a must for electrical work and strippers are really, really handy. Again, for precision hand tools, I do not skimp. A word of caution is in order though: do not use wire cutters for cutting anything other than soft materials. Steel music wire will ruin them. My brand of choice is Xcelite, although I do keep a cheap pair or two around to custom shape on a bench grinder.

That is it for basic tools. While there are many different tools here, you can keep things to a minimum. You don't need to buy every metric, fractional, letter, and decimal drill, for instance, nor do you need to buy every file shape you can imagine. Don't be lured into really cheap tools and don't feel compelled to buy one of everything where there is a variety.

As far as materials are concerned, consider the following:

Evergreen scale models "side-walk": This is basically a polystyrene sheet that is pre-scribed in a ruled pattern. This allows you to snap off pre-measured square or rectangular sections and provides an accurate ruling to place other components.

I match this up with box sections of Plastruct, using the evergreen as a skin. I prefer to use the 1/4", 3/8", and 1/2" sizes, though the finer gradations can be used to fit contoured sections. This is the staple of my construction and I always keep some around.

Polystyrene sheet, 0.040" thick: Use this for round shapes or small pieces. Other thicknesses are handy, as well, to make spacers and cosmetic features and for areas where stronger assemblies are required.

Plastruct shapes, like "L" beams and square sections: These can be made to build mounts for servos, as well as other structural components. Use the thick-walled, gray stuff. I personally like the 1/4", 3/8", and 1/2" square tubes best. I use them to make structural shapes that I attach other components to. The thick-walled stuff is more robust and you can actually use self-tapping screws.

Double-sided tape: Your local hobby store should have some thin rolls of servo tape available. This is excellent for — well, you guessed it — servos. It is also handy for mounting subassemblies as well, provided that you have a large surface area. I will sometimes build a 1" x 1" flat area onto a subassembly, like a sensor platform that can be double-sided taped to other parts of the robot with similarly large areas. In this way, I can experiment with a variety of sensors without the hassle of fasteners.

Mechanical components that will cause stress — like motors or servos — may not lend themselves to this method, though.

Wire Cutter and Stripper

Plastruct Bondene

Squadron Putty

Squadron putty: This is useful for filling gaps if you want to paint your creation. Do not build up huge volumes. Fill large gaps with thin, styrene pieces and then use the putty in a thin veneer. Thick sections of putty will crack and they take a long time to dry. The green is for use on military miniatures, while the white is a neutral color.

Epoxy: Five minute epoxy is good if you need a quick joint, but, for ultimate strength, I like JB Weld or one hour cure epoxy. Be warned that epoxy will flow and JB Weld is attracted to magnetic fields. You can strengthen joints with other materials, like thread or even cotton. Cotton also helps keep epoxy contained.

Thick and thin Cyanoacrylate adhesive and accelerator: Special care must be taken with Cyanoacrylates. Urban legend has it that they were developed by the military as a chemical warfare agent, to be squirted all over soldiers and chemically formulated to bond to flesh. What I do know is that they are used in surgery and, this being the case, gluing stuff to yourself qualifies as a major bummer. I can only imagine the horror of gluing your eyes.

That being said, they are very convenient and remarkably strong. Thin formulations allow you to use capillary action to bond large areas together and thick formulations have gap-filling properties. The accelerator will cause instant bonding.

Despite its convenience, I rarely use it for construction, saving it for repairs. The one exception is gluing servo horns to flat surfaces. When I use accelerator, I do not spray it everywhere, but, instead, dip a thin stick into it and touch that to the joint.

Styrene adhesive and needle applicator: Plastruct Bondene for Styrene and ABS is my preferred method of bonding Styrene plastics. I like to use a needle applicator and allow capillary action to carry the adhesive through the joint. Care must be taken not to touch your needle applicator to the glued joint, thereby clogging your applicator with melted Styrene.

Basic gluing wisdom: Make sure your components are clean. Contamination can foul or weaken bonded joints. Epoxies work by making a molecular intermediary between materials, while Styrene adhesives actually melt the materials with solvents, creating a sort of "weld."

Some plastics are cast with mold release or other lubricants in them or exhibit other "slippery" properties; you will likely have to resort to mechanical fasteners to join to them. This is often the case with the gearboxes and mechanical linkages of toys and no amount of surface preparation can help you.

Brass tubing: Brass tubing can be used for a variety of applications, especially where plastics are not

robust enough. You can make axles and bearings for reciprocating or rotary motion. Brass can be polished to a luster and soldered with a soldering gun or even brazed. Other brass shapes are useful, too, like the square profiles.

Brass' conductive properties can allow you to make electrical connections to it, although it oxidizes to a non-conductive finish. There are a variety of silver-plating powders that allow you to apply a thin silver finish. This is very useful for making bumper switches or other electrical contacts.

For the best appearance, polish with Brasso, wash, and quickly spray paint with clear finish before the brass oxidizes.

Graph paper: By tracing your components to be mounted on graph paper, you can quickly scale down to make complete sketches. This works well with the Evergreen sidewalk tiles, since they are already in convenient increments.

Shrink tubing: Shrink tubing should be used on all electrical connections. It adds strength to the joint and helps guide wires. I like to use red for my positive connections, just as a visual "key" so that I maintain proper polarity.

Colored ribbon cable: A 12' length of 36-conductor ribbon cable can last many years. By using an X-acto knife to start a tear between conductors, you can "peel" off as many conductors as you need for a point-to-point run. I use black for negative, red for +5 volt, and white for battery voltage, along with other color combinations for other signals. Remember that ribbon cable is coded with the same colors and in the same order as resistors are coded.

With these basic guidelines, you can quickly play with many concepts and even build finished products. These tools and materials will allow you to produce whatever level of cosmetic detail you wish and allow for a reasonable level of mechanical tolerance.

In a future column, I have a neat little robot with a bunch of sensors and servos in store. I will be using most of these techniques and will show you how to apply them, but, to "whet your appetite," I built a little desktop rover in about 10 minutes, just to give you an idea how easy things can be. **NV**

Resources

www.evergreenscalemodels.com/Sheets.htm

www.plastruct.com/

www.ksmetals.com/

www.grobetusa.com

Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at: **TJBYERS@aol.com**.

What's Up:

It's all about power, beginning with a dB chart and a pinout chart for IC voltage regulators. Circuits include a voltage regulator and current regulator. There's a story about used NiCds. Reader C. L. Larson shows how to modify TV sound output. Finally, turn your Xbox into a Linux PC.

Q. In the May 2004 issue, you answered a letter about a guitar preamp with the statement that the circuit provides a 3 dB gain (double the input voltage). A 3 dB gain would multiply the input voltage by 1.414. It would take 6 dB to double the input voltage.

R. A. Rosien
via Internet

A. It was a slip of the pen. I meant power and yet I wrote voltage. Mea culpa. However, the subject of decibels often confuses the newcomer to electronics and even us old-timers have an occasional lapse of memory regarding decibels. For the benefit of both, let's take a look at the decibel (Table 1).

The ratio between a whisper and a shout is so great that the legendary Alexander Graham Bell developed a logarithmic system to measure it — a system based on the bel. In this system, the power increases by 10 for each bel. (The Richter scale of measuring earthquakes also uses a log scale.) A decibel (abbreviated dB) is one-tenth of a bel.

Looking at Table 1, you'll notice that the power doubles for each 3 dB step. That is, 3 dB is twice as much power as 0 dB, 6 dB is four times greater, and 9 dB is eight times the power. The dB power ratio can be easily calculated by raising the number 10 to the log value (dB).

dB	Voltage	Power	dB	Voltage	Power
0	1.00	1.00	25	17.8	316.2
0.5	1.06	1.12	30	31.6	1,000
1	1.12	1.26	35	56.3	3,162
2	1.26	1.58	40	100	10,000
3	1.414	2.00	45	178	31,623
4	1.58	2.51	50	316	100,000
5	1.78	3.16	55	562	316,228
6	2.00	3.98	60	1,000	1,000,000
7	2.24	5.01	65	1,778	3,162,278
8	2.51	6.31	70	3,162	10,000,000
9	2.82	7.94	75	5,623	31,622,777
10	3.16	10.0	80	10,000	100,000,000
11	3.55	12.6	85	17,782	316,227,766
12	3.98	15.8	90	31,623	1,000,000,000
13	4.47	20.0	95	56,234	6,162,277,660
14	5.01	25.1	100	100,000	10^{10}
15	5.62	31.6	105	177,828	3.16×10^{10}
15.5	5.96	35.5	110	316,228	10^{11}
17	7.08	50.1	115	562,341	3.16×10^{11}
18	7.94	63.1	120	1,000,000	10^{12}
19	8.91	79.4	130	3,162,278	10^{13}
20	10.0	100.0	140	10,000,000	10^{14}

Table 1. Decibel Voltage and Power Ratios

Voltage, on the other hand, is equal to V = current/power. In logarithmic language, that's a 20 ratio, not 10. The formula is Volts (dB) = $10^{(dB/20)}$ and can be calculated on the PC by using the "x^y" function of the Windows calculator. First, divide the dB value by 20 and save it to memory (MS). Clear the calculator using the Esc key, type in 10, click on x^y, read the memory (MR), and hit Enter. That is your voltage ratio.

The decibel system has another advantage in that the ratios can be added and subtracted without going through a lot of math. For example, let's say that you want the voltage ratio between 25 and 40 dB or between 40 dB and 34 dB. Just subtract the values — negative numbers are permitted and represent an attenuation rather than amplification. Run your answer through the calculator (or look it up in Table 1) and you will have your power and voltage ratios. In the first example, 40 minus 25 is 15 dB for a voltage gain of 5.62. In the second, -6 dB equals a voltage attenuation of exactly half with one-fourth the power.

Wide-Range Current Regulator

Q. I'm refurbishing a pair of old Hebern cryptographic machines and I think I need something rather peculiar in the way of a power supply.

The machine (from an electrical point of view) looks like a voltage source that is connected to the "left stator." Then there is an alternating sequence of rotor-stator-rotor-stator-rotor-stator-rotor-stator-rotor, ending with the "right stator." There are 26 possible paths through each rotor and each stator. The left rotor is connected to a keyboard; depressing a key "wets" one of the 26 contacts on the left rotor. The power is then transmitted through the rotors and stators to the right rotor, which illuminates one of 26 light bulbs to indicate the enciphered letter. The orientation of the rotors to the stators changes on a letter-by-letter basis.

I have rewired the rotors so that the resistance through each of the 26 possible paths in each rotor is less than 1 Ω. That was, comparatively, easy. The problem is that the intermediate stators are built out of contacts and springs (98 parts per stator!) and the resistance through each of the 26 paths in the stators is not uniform — varying from about 1 Ω to about 4 Ω, depending on the particular stator and path.

Can you show me how to build a power supply that has the following characteristics?

• If it sees an open circuit (say, more than 100 Ω), it doesn't panic and produces no output.

• If it sees a resistance of 10 Ω, it cranks out 3 volts at about 0.3 amps.

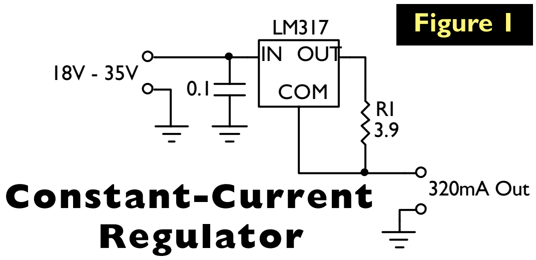
• If it sees a resistance between 10 and 100 Ω, it puts out whatever voltage is required to develop 0.3 amps.

Peter Ingerman
via Internet

A. What you need is a constant current power supply of 0.3 amps or 300 mA. This is easily accomplished using an LM317 adjustable voltage regulator (Figure 1). Resistor R1 determines the output current of the LM317 by setting the current of the internal reference voltage, which is 1.25 volts. If R1 is 1.25 Ω, then the output current will be 1 amp; a 3.9 Ω, 1/2 watt resistor limits the current to 320 mA.

Now, let's determine how much

Figure 1



Constant-Current Regulator

voltage is needed to push 320 mA through a 100 Ω load. Using Ohm's Law, E = IR = 0.32 x 100 = 32 volts. Because the LM317 needs at least 3 volts to operate, the minimum input voltage is 35 volts DC. If you can live with an upper limit of 50 Ω, the minimum input voltage is 18 volts, which is easily obtained from a cheap wall-wart. Be sure to heatsink the IC because it can run hot — up to 10 watts with a shorted output.

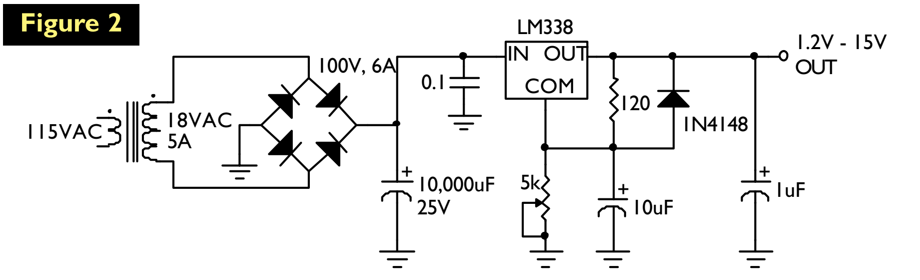
High-Power Variable Voltage Regulator

Q. Could you suggest a schematic for a variable power supply to replace the electronics inside my old HeathKit (BE-5) battery eliminator? I don't need the 6 volt option, but something with better 12 volt regulation would be nice. I'm thinking of replacing the variable transformer with a pot and a fixed transformer — as long as it fits in the original cabinet, which I have grown to love.

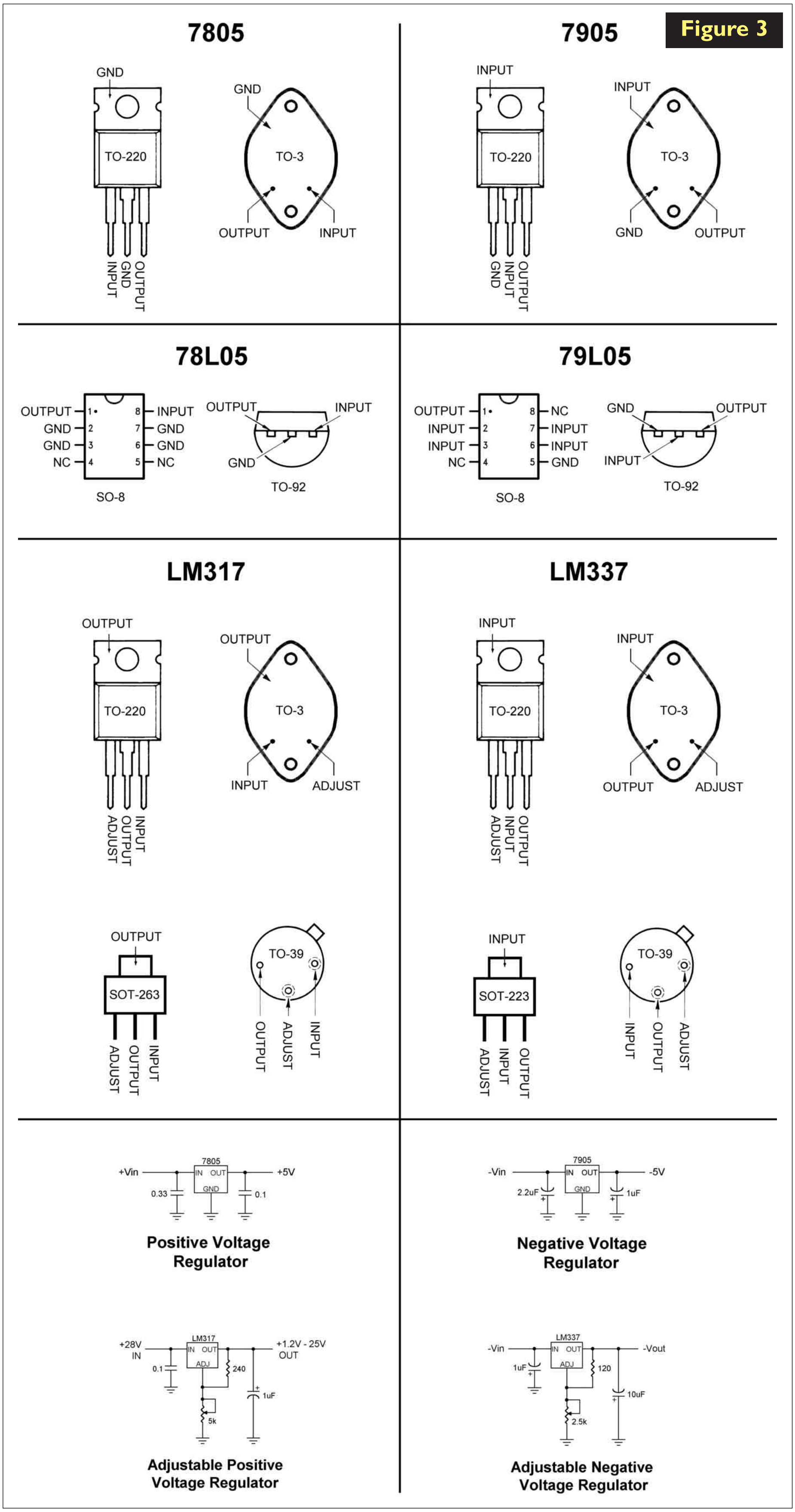
Jim
via Internet

A. This is a simple request that requires little more than an LM338 (Figure 2). Basically, the circuit is a full-wave rectifier, followed by a

Figure 2



15-volt, 6-amp Variable Power Supply



variable voltage regulator IC. The 5K resistor is used to set the output voltage to between 1.2 and 15 volts.

The hard part will be finding a power transformer, but its rating isn't critical. Anything between 15 and 24 volts will work. The output voltage range will change, though, with the output being 3 volts less than the transformer's rating. Me? I would keep your present transformer and wire the secondaries in series.

Remount it to clear the front panel, if you can. (You don't need to keep the choke or old electrolytics.) Keep the ammeter and voltmeter as they were — in series and parallel with the output, respectively. Don't be tempted to use the old rectifiers. Replace them with a 100 volt, 6 amp bridge rectifier, like the PB61DI from Digi-Key (800-344-4539; **www.digikey.com**). Be sure that the LM338 and rectifier are well heatsinked.

Voltage Regulator Pinouts

Q. Regarding pinouts ("Pinout Chart," April 2004), why do all three-pin voltage regulators use different pinouts (7805, 78L05, 317, 337, etc.)? I think all the TO-92 and TO-220 packages should pinout the same way. I can't for the life of me guess why they're all different. This seems as dumb as putting diodes in SOT-23 packages and randomizing the pinouts for each part number.

Chuck Larson
Largo, FL

A. Actually, SOT-23 diode packages do vary, but that doesn't answer your question. I assume the pins are changed to protect the innocent — that is, to safeguard a circuit in case a negative regulator is accidentally placed in a positive socket. Take the 7805 and 7905 TO-220 case, for example. Note that the GND and input pins are reversed. This prevents the input voltage from going to the IC should a wrong polarity regulator be inserted. No voltage in

means no voltage out and the device is protected, but you'd better make sure the power supply is fuse-protected because the input is now grounded!

That said, here's a pinout chart of the most popular three-pin regulators (Figure 3). On purpose, I didn't include a prefix — such as LM — unless necessary. That's because a 78L05 can be labeled as KA78L05, L78L05, MC78L05, etc. Although the electrical ratings may vary from vendor to vendor, the pinout is always the same. *(A PDF version of this chart can be downloaded from our website,* ***www.nutsvolts.com*** *under the name PINOUTS_Vreg.PDF. — Editor Dan.)*

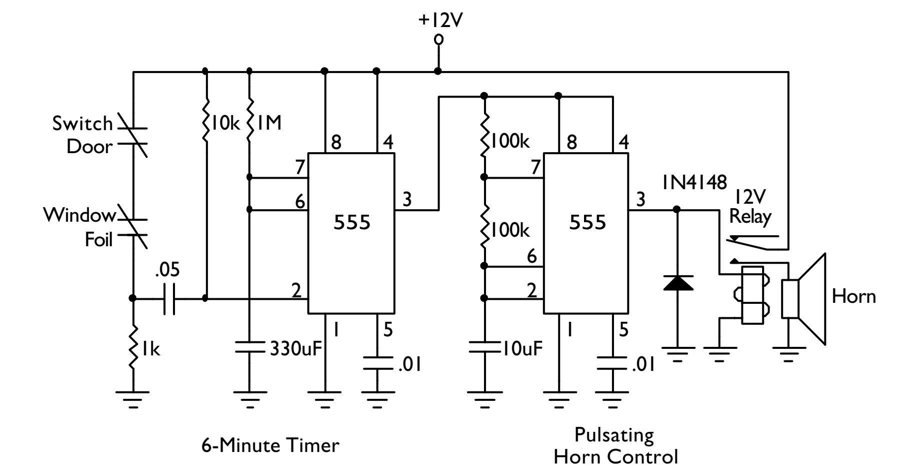


Figure 4 **Outbuilding Alarm**

Solar Burglar Alarm

Q. I am in need of an alarm for a new storage building where I do not have utility power. Instead, I want to power the alarm from a 12 volt car battery that I will keep charged with a solar panel.

Therefore, I need a timed disconnect (probably about 10 minutes) to keep the battery alive and the sirens from being worn out. I am within eyeshot (1/2 mile) of another farm, but not within real earshot, so the sirens (one inside and one outside) would be mostly a psychological scare to anyone breaking the circuit.

Gary A. Micanek
via Internet

A. A single 555 timer would serve your purpose. Going on your requirements, I assume you want to use the window foil and magnetic door switch; that's how the timer is wired in (Figure 4). When the circuit is broken, a negative pulse triggers the pin 2 input of the 555 and sounds your sirens for about six minutes. The only way to reset the alarm is to reestablish the loop's continuity. If all you're protecting is a door, closing the door will reset the alarm; a broken window is another story.

It's been my experience, though, that a droning siren attracts little attention, whereas a pulsating alarm — like the kind they use in car alarms — makes people take a look see. So, I added a second section — one that turns the siren on for 1-1/2 seconds and off for about 1/2 second. A single 556 IC can replace the two 555s.

Dead NiCds, May They RIP

Q. I have been looking for a way to recharge and specifically recondition the 9.6 volt stick batteries used in the older Makita series of tools. I have the newer 18 volt DeWalt equipment, but I find that, for light work, the Makita is easier to get into places than the larger drills.

I purchased the better quality recharge unit, but it doesn't produce a better result than the original — just more lights. I have searched the 'net for a reconditioner or a good value in new batteries, but I have not found either. Do you have a circuit which would at least recondition the stick pack in order to recharge them?

Tim Edwards
via Internet

CP	J	K	S	R	Q	Q
x	x	x	1	0	1	0
x	x	x	0	1	0	1
x	x	x	1	1	1*	1*

* Unstable

Table 2. 4027 Logic

A. I'm sorry, but a NiCd battery is like a phone calling card. You have so many minutes of use and, when they're gone, they're gone. That is, you can only recharge the battery so many times before it wears out. This can vary between 500 and 1,000 recharges, but, when a battery's number is up, it's up forever. You can't recondition it. (Although you can try zapping them for a temporary fix. See the September 2000 "Q & A.")

The good news is that the 9.6 volt stick configuration is very popular and it is even used in some flashlights. This means you should be able to buy them at a discount from several sources. Pay attention, though. They have changed since you bought your original tool and now come in 1.3 AH, 2.2 AH, and NiMH versions. All will work, but some work better than others — depending on how often you use the tool and for how long at a time.

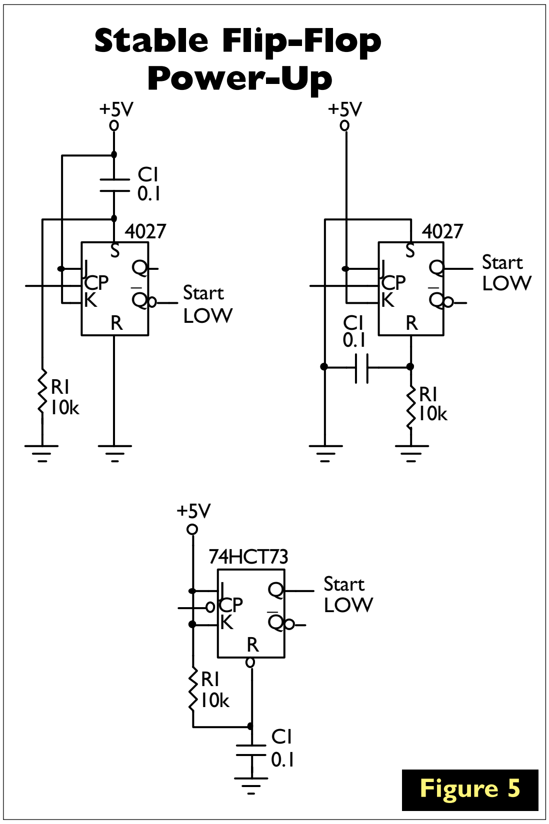


Figure 5

Take It Easy

Q. In the March 2004 issue, I saw your answer about restoring old electrolytics. I have a couple of Tektronix oscilloscopes and some other test equipment that have not been used for over 20 years. What is the correct procedure to safely return them to working condition? No doubt, the electrolytics all need reforming.

Joseph De Luccia
Saddle Brook, NJ

A. If it's tube operated, remove all the tubes, except for the rectifier tube (typically something with a 4 as the last digit, like a 5U4 or 6X4). Next, find the B+ output capacitor and monitor the voltage across it with a DMM. With the scope plugged into the Variac, turn on the power switch and slowly advance the Variac voltage to about 60 VAC — half the AC line voltage. If the fuse doesn't pop, the B+ voltage will be somewhere around 120 to 200 volts.

Let the unit sit for an hour or two and monitor the chassis for hot spots — especially the electrolytics. Next, power down, replace the tubes, and — this time — slowly increase the line voltage to 100% over a period of a minute or two. If all's well, you should be back in business.

Unfortunately, this method only guarantees that the caps aren't shorted; it won't tell you if they are open, which will lead to excessive ripple, but that's a topic for another column.

Not All Websites Are Forever

Q. I tried to connect to the three 555 timer websites listed in the "Commercial Grade Delay Timer," in the May 2004 issue. The first one directed me to a questionable search service and the other two led nowhere. Please test these out in the future.

Paul Frankle
via Internet

A. These websites are tested both by me and the editors at press time. In fact, I tested those you mention just now and discovered that only the first one is, indeed, no longer available. Unfortunately, that's the way it works because the site will be dropped unless the person pays the monthly server bill. The other two are still up and running.

However, I have noticed that the fonts that *Nuts & Volts* and most other magazines use appear in such a way that, sometimes, a reader will use an I (letter) when, in fact, the website character is a 1 (numeral), so you may want to try both combinations before giving up.

Guaranteed Flip-Flop State On Cold Boot

Q. I have to start a motor with one button and keep the motor circuit active high while other buttons are depressed. The problem is that, during a cold power-up of a typical flip-flop, the outputs are unpredictable. This causes the motor to run when it is not desired. I need a circuit that will always have one output low at power-up (motor normally off). The design I'm thinking of uses a 4027 dual JK flip-flop,

but I'm open to suggestions.

Doug Adams
via Internet

A. Whatever the flip-flop, it's easy to set the states of the outputs on power-up using the set and reset inputs. There are two types of JK flip-flops: set/reset and asynchronous reset. Let's examine the set/reset 4027 first.

Its logic table (Table 2) shows that the outputs can be forced into any state through the set and reset pins, regardless of what exists on the clock (CLK), J, or K inputs. To create a stable state at power-up, one of these inputs has to lag behind the others.

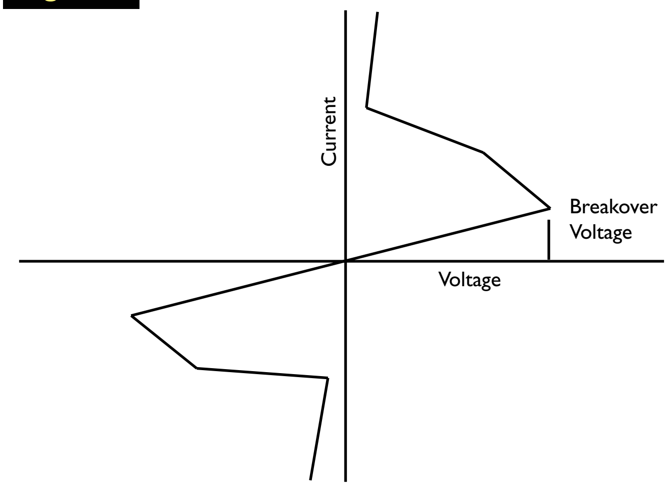
An RC combination does just that, as shown in Figure 5. When power is applied, C1 charges through R1 until it reaches +5 volts, which forces their respective outputs low and arms the flip-flop.

The logic table for an asynchronous reset 74HCT73 is shown in Table 3. As before, the capacitor pulls the reset pin low at power-up and forces the Q output low, then charges to +5 volts for toggle operation.

CP	J	K	R	Q	Q
x	x	x	0	0	I

Table 3. 74HCT73 Logic

Figure 6 **SIDAC Parameters**



Triac's Sidekick: Sidac

Q. I recently came across the names of two electronic components that are unfamiliar to me: sidac and stabistor. Could you explain them? If you know of any more "weirdo" components, please let me know their names and functions.

John Agugliaro
via Internet

A. You know what a diac is, right? Well, the sidac is the triac equivalent of a diac. Now in English: The sidac is a bidirectional negative resistance device. Let's place a voltage across a sidac and see what happens.

At low voltages (typically under 70 volts), the sidac behaves like a switch in its off state. As the voltage across the sidac is increased, a point is reached where the switch turns on and conducts current heavily — and will continue to do so until the voltage is removed (Figure 6).

The difference between a diac and a sidac is polarity. A diac is a polarized device that acts like a diode — that is, it has one-way current flow, whereas a sidac can conduct current in both directions. It's most commonly used to trigger triac gates, strobe xenon flash tubes and HID, ignitors for natural gas, and generators for high-energy pulses for flyback operations. A datasheet with applications **www.littelfuse.com/data/Data_Sheets/E9Sidac.pdf**) tells a more complete story.

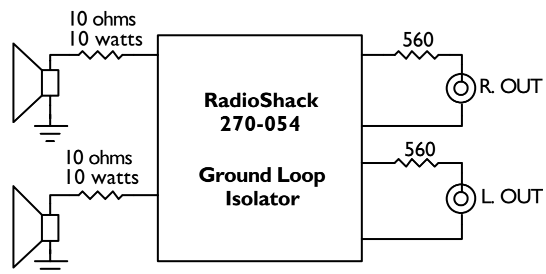
The stabistor is a low voltage zener diode with one to four P-N junctions, where the forward voltage drop across the junctions provides superior dynamic impedance to low voltage zener diodes, which use avalanche electron tunneling. In English: It's kind of like stacking a bunch of 1N4001 diodes in series to achieve a stable voltage reference in the range of 0.7 to 3.7 volts by forward biasing them. The forward current is critical to the actual voltage, as shown in

the Microsemi (**www.microsemi.com/datasheets/SA7-29.PDF**) datasheet.

Reader's Circuit

I bought a 31" Sanyo TV for $300.00 only to discover that the audio output jacks did not respond to the volume control. I phoned Sanyo and found that they had a "hum" problem and had decided to use a fixed amplitude output instead of using a couple of transformers to send the speaker drive to the external jacks. In this way, they offered to provide me with the version with volume-controlled rear jacks for only $300.00 more.

I took the TV apart, removed the coupling caps from the fixed amplitude drive, jumpered the speaker drive to the output jacks, and promptly produced the hum problem. Then I added a RadioShack 270-054 ground loop isolator and have the completed $600.00 version — working perfectly — for the initial $300.00, plus an additional $16.00, and some attitude.



Sanyo TV Sound Modification

Figure 7

I also put a 10 Ω, 10 watt resistor (RS 271-132) in series with each speaker (Figure 7). This has the effect of lowering the bass cut-off frequency from 90 Hz to 40 Hz. While the four inch speakers in the TV are useless at 40 Hz, the lower frequencies are now available at the rear jacks, so my massive home stereo can make use of them. I was wary about the (unpublished) impedance of the ground loop isolator — lest it load down the lower frequencies — but it tested out well on my scope and eats up about 1.5 dB at 40 Hz after the 560 Ω protection resistors that are in series with the Sanyo audio-out jacks.

In short, the frequency response is flat within 1.5 dB from 40 Hz to 50 kHz. When the 560 Ω resistor was not included, the frequency response of the ground loop isolator was dead flat from 20 Hz to 20 kHz and well beyond.

C. L. Larson
via Internet

MAILBAG

Dear TJ,

I looked at your solution for "Sink the Bismarck" (February 2004) and, quite frankly, the solution is worse than the problem. The contacts of a compact reed relay like RadioShack's P/N 275-232 are not designed to carry heavy currents — such as the current demands of a DC motor.

The reason for this is that the contacts will "arc weld" themselves together after a few operations, especially with the sparks generated because of the lack of a diode in parallel with the motor to limit the back EMF generated when the relay turns off and, without a diode in parallel with the relay coil, the back EMF generated when the transistor turns off will destroy the poor MPSA14.

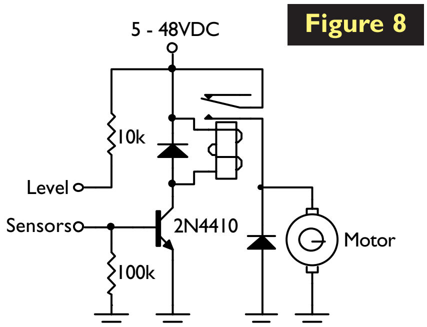
Please remember that most of the people asking for help in "Q & A" are novices and they should be guided with solutions that reflect proper design practices.

Daniel Bernes
via Internet

Response: *That circuit was designed for a specific application, where space was at a premium and the motor current requirements were well within the specs of the reed relay — even without the EMF damper diode. You're right, though, larger motors require larger relays and EMF protection. Here is the circuit to use for those applications* (Figure 8).

— TJ

Figure 8



Bilge/Sump Pump Sensor

Dear TJ,

I enjoy your "Q & A" column very much, but there is a problem with Figure 4 ("SSR Meets MCU") in the March 2004 issue. The 2N2222A won't work reliably with loads approaching 800 mA. I looked up the specs for this transistor and it's rated at 500 mA, with 200 mA preferred. For larger load currents, substitute an NPN Darlington transistor in a power package — such as a TIP-140 — and attach a small heatsink to the transistor tab for currents greater than 400 mA.

Ernie Worley
via Internet **NV**

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www.josephpalmer.com/planes/Airplane.shtml

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www.bestpaperairplanes.com/

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